

Some Account Of The
Life 1873 vol. 1

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SOME ACCOUNT
OF
THE LIFE, &c

MR. JOHN SMEATON, F.R.S. a very celebrated Civil Engineer, and author of the ensuing Reports, was born the 28th of May, 1724, at *Austhorpe*, near *Leeds*, *Yorkshire*, in a house built by his grandfather, where the family have resided ever since, and where our author died the 28th of October, 1792, in the 68th year of his age.

Mr. SMEATON seems to have been born an Engineer. The originality of his genius and the strength of his understanding appeared at a very early age. His playthings were not those of children, but the tools men work with; and he had always more amusement in observing artificers work, and asking them questions, than in any thing else. Having watched some mill-wrights at work, he was one day, soon after, seen (to the distress of his family) on the top of his father's barn, fixing up something like a windmill. Another time, attending some men who were fixing a pump at a neighbouring village, and observing them cut off a piece of bored pipe, he contrived to procure it, of which he made a working pump, that actually raised water. These anecdotes refer to circumstances that happened when he was hardly out of petticoats, and probably before he had reached the 6th year of his age. About his 14th or 15th year, he made for himself an engine to turn rose-work, and he made several presents to his friends of boxes, in wood and ivory, turned by him in that way.

His friend and partner in the *Deptford* Water-works, Mr. JOHN HOLMES, visited Mr. SMEATON, and spent a month with him at his father's house, in the year 1742, when consequently our author was about 18 years of age.

Mr. HOLMES

Mr. HOLMES could not but view young SMEATON's works with astonishment: he forged his own iron and steel, and melted his own metals: he had tools of every sort for working in wood, ivory and metals. He had made a lathe, by which he had cut a perpetual screw in brass, a thing very little known at that day.

Thus had Mr. SMEATON, by the strength of his genius, and indefatigable industry, acquired, at 18 years of age, an extensive set of tools, and the art of working in most of the mechanical trades, without the assistance of any master, and which he continued to do a part of every day when at the place where his tools were; and few men could work better.

Mr. SMEATON's father was an attorney, and was desirous of bringing his son up to the same profession. He was therefore sent up to London in 1742; where for some time he attended the courts in *Westminster-Hall*; but finding that the profession of the law did not suit *the bent of his genius*, (as his usual expression was,) he wrote a strong memorial to his father on the subject, whose good sense from that moment left Mr. SMEATON to pursue the bent of his genius in his own way.

Mr. SMEATON after this continued to reside in *London*, and about the year 1750 he commenced philosophical instrument maker, which he continued for some time, and became acquainted with most of the ingenious men of that time.

This same year he made his first communication to the Royal Society; being an account of Dr. KNIGHT's improvements, of the Mariner's Compass. Continuing his very useful labours, and making experiments, he communicated to that learned body, the two following years, a number of other ingenious improvements, as will be enumerated in the list of his writings, at the end of this account of him.

In 1751 he began a course of experiments, to try a machine of his invention for measuring a ship's way at sea; and also made two voyages, in company with Dr. KNIGHT, to try it, as well as a compass of his own invention.

In 1753 he was elected a member of the Royal Society; and in 1759 he was honoured with their gold medal, for his paper concerning the natural powers of water and wind to turn mills, and other machines depending on a circular motion. This paper, he says, was the result of experiments made on working models in the years 1752 and 1753, but not communicated to the Society till 1759; having, in the interval, found opportunities of putting the result of these experiments into real practice, in a variety of cases, and for various purposes, so as to assure the Society he had found them to answer.

In 1754, his great thirst after experimental knowledge led him to undertake a voyage to Holland and the Low Countries, where he made himself acquainted with most of the curious works of art so frequent in those places.

In December 1755, the *Edystone Lighthouse* was burnt down, and the proprietors, being desirous of rebuilding it in the most substantial manner, enquired of the Earl of MACCLESFIELD, then President of the Royal Society, who he thought might be the fittest person to rebuild it; when, he immediately recommended our author. MR. SMEATON accordingly undertook the work, which he completed with stone in the summer of 1759. Of this work he gives an ample description in a folio volume, with plates, published in 1791; a work which contains, in a great measure, the history of four years of his life, in which the originality of his genius is fully displayed, as well as his activity, industry and perseverance.

Though Mr. SMEATON completed the building of the *Edystone Lighthouse* in 1759, yet it seems he did not soon get into full business as a Civil Engineer; for in 1764, while in *Yorkshire*, he offered himself a candidate for one of the receivers of the *Derwentwater* estate; in which he succeeded; though two other persons, strongly recommended and powerfully supported, were candidates for the employment. In this, he had the faithful and friendly support of Sir FRANCIS GOSLING, Alderman of *London*, and one of the Commissioners. That estate was forfeited in the year 1715, and the revenues thereof were applied by Parliament, towards the fund of *Greenwich Hospital*. It consists of mines of lead, containing much silver, as well as lands.

It required, better than common management, and above all, that knowledge absolutely necessary to bring mines of lead and coal to the most productive effect. This was the object of the Commissioners, and it has been amply repaid. Machines of all kinds, and better means on a great plan, were devised for a more easy and ample working these mines, by Mr. SMEATON : while, the correct judgment, patient industry, and great abilities and sincerity of Mr. WALTON the younger, of *Farnacres* near *Newcastle*, (his partner in the duty of receiver,) taking upon himself the management and the accounts, left Mr. SMEATON, leisure and opportunity, to exert his abilities on these works, as well as to make many improvements in the whole of this estate of *Greenwich Hospital*.

By the year 1775 he had so much business, as a Civil Engineer, that he was desirous of resigning the appointment for that Hospital, and would have done it then, had not his friends prevailed upon him, to continue in the office about two years longer.

Mr. SMEATON having, thus got into full business as a Civil Engineer, it would be an endless task to enumerate all the various concerns he was engaged in. A very few of them however may be just mentioned in this place. —He made the river *Calder* navigable ; a work that required great skill and judgment, owing to the very impetuous floods in that river. —He planned, and attended for some time, the execution of the great, or *Forth* and *Clyde*, canal in *Scotland*, for conveying the trade of the country either to the *Atlantic* or *German Ocean*. • When this work had been executed from the *Forth* towards the *Clyde*, as far as a point intended for the junction of a collateral canal to *Glasgow*, the work stopped, and was discontinued a considerable time, by the funds being exhausted. Before that period, Mr. SMEATON had declined accepting his salary, which was five hundred pounds a year, that he might not be prevented from attending to the multiplicity of other business ; and conceiving the resident engineer, Mr. M'KELL, was fully competent to conduct it afterwards. After a lapse of some time, the work was resumed, by public aid, and has been carried on, and lately completed, under the direction of Mr. WHITWORTH, to the great benefit of trade and that country.

On opening the great arch at *London Bridge*, by throwing two arches into one, and the removal of a large pier, the excavation, around and underneath the sterlings of that pier, was so considerable, as to put the adjoining piers, that arch, and eventually the whole bridge, in great danger of falling. The previous opinions of *some* were positive, and the apprehensions of *all* the people on this head were so great, that many persons would not pass over or under it. The Surveyors employed were not adequate to such an exigency. Mr. SMEATON was then in *Yorkshire*, where he was sent for by express, and from whence he arrived in town with the greatest expedition. He applied himself immediately to examining the bridge, and to sound about the dangerous sterlings, as minutely as he could. The Committee of Common Council adopted his advice; which was, to re-purchase the stones of all the City Gates, then lately pulled down, and lying in *Moorfields*, and to throw them pell-mell, (or *piere perdu*,) into the water, to guard these sterlings, preserve the bottom from further corrosion, raise the floor under the arch, and restore the head of water necessary for the water-works to its original power; and this was a practice, he had before, and afterwards adopted on other occasions. Nothing shews the apprehensions of the bridge falling, more, than the alacrity with which his advice was pursued: the stones were re-purchased that day; horses, carts, and barges were got ready, and the work instantly begun, though it was Sunday morning. Thus Mr. SMEATON, in all human probability, saved *London Bridge* from falling, and secured it till more effectual methods could be taken.

In 1771 he became, jointly with his friend Mr. HOLMES above-mentioned, proprietor of the works for supplying *Deptford* and *Greenwich* with water; which, by their united endeavours, they brought to be of general use to those they were made for, and moderately beneficial to themselves.

Astronomy was one of Mr. SMEATON's most favorite studies; and he contrived and made several astronomical instruments for himself and friends. After fitting up an observatory at his house at *Austhorpe*, he devoted much of his time to it when he was there: even in preference to public business, much of which he declined for the purpose of applying his attentions to private study, particularly to the subject of astronomy.

About the year 1785 Mr. SMEATON's health began to decline; and, in consequence, he then took the resolution to avoid new undertakings in business as much as he could, that he might thereby also have the more leisure to publish some accounts of his inventions and works. Of this plan, however, he got no more executed than the account of the *Edystone Lighthouse*, and some preparations for his intended treatise on mills; for he could not resist the solicitations of his friends in various works. Mr. AUBERT, whom he greatly loved and respected, being chosen chairman of *Ramsgate Harbour*, prevailed upon him to accept the office of Engineer to that harbour, an office established at that time, as, he had been occasionally consulted only, previous thereto; and to *their joint efforts* the public are chiefly indebted for the improvements that have been made there, within these few years; which fully appears in a Report that Mr. SMEATON gave in to the Board of Trustees in 1791, which has been published in various ways.

The powers of his mind were beginning to fail, in the observation of his intimate friends, and afterwards of all. He is known to have said, on talking of his health, that he found he had suffered more from the application he paid to the scheme, design, and proposition of a Canal from *Birmingham* to *Worcester*, (which was then very much contested in Parliament) than all the business he had ever met with.

Strong exertions were necessary; which, if he had been vigorous as he was wont, it would have sat easy upon him; but alas! with the deficiency then commenced, it was hard labour indeed, and thereby promoted, the ruin fast approaching, and much to be lamented.

This lamentable tale is told, for the instruction of those engaged, and so circumstanced, at that period of life, when the powers of the mind are borne down by the complication and vastness of an object submitted to it.

The bill for that work passed by a small majority; but the difficult and contested part of that work has not as yet been attempted. He was not the proposer, but the supporter of that proposition.

It had for many years been the practice of Mr. SMEATON to spend part of the year in town, and the remainder in the country, at his house at *Austhorpe*. On one of these excursions in the country, while walking in his garden, on the 16th of September, 1792, he was struck with the palsy, which put an end to his useful life the 28th of October following, to the great regret of a numerous set of friends and acquaintance.

The great variety of mills constructed by Mr. SMEATON, so much to the satisfaction and advantage of the owners, will shew the great use he made of his experiments in 1752 and 1753. Indeed he scarcely trusted to theory in any case where he could have an opportunity to investigate it by experiment; and for this purpose he built a steam-engine at *Austhorpe*, that he might make experiments expressly to ascertain the power of the OLD or NEWCOMEN'S steam-engine; which he improved and brought to a much greater degree of certainty, both in its construction and powers, than it was before.

During many years of his life, Mr. SMEATON was a constant attendant on Parliament, his opinion being continually called for. And here his natural strength of judgment and perspicuity of expression had their full display. It was his constant practice, when applied to, to plan or support any measure, to make himself fully acquainted with it, and be convinced of its merits, before he would be concerned in it. By this caution, joined to the clearness of his description, and the integrity of his heart, he seldom failed, having the bill he supported, carried into an act of Parliament. No person was heard with more attention, nor had any one ever more confidence placed in his testimony. In the Courts of Law he had several compliments paid to him from the Bench, by the late Lord MANSFIELD and others, on account of the new light he threw upon difficult subjects.

As a Civil Engineer, he was perhaps unrivalled, certainly not excelled, by any one, either of the present or former times. His building the *Edystone Lighthouse*, were there no other monument of his fame, would establish his character. The *Edystone Rocks* have obtained their name from the great variety of contrary sets of the tide or current in their vicinity. They are situated

situated nearly S. S. W. from the middle of *Plymouth Sound*. Their distance from the port of *Plymouth* is about fourteen miles. They are almost in the line which joins the *Start* and the *Lizard Points*; and as they lie nearly in the direction of vessels coasting up and down the *Channel*, they were unavoidably, before the establishment of a lighthouse there, very dangerous, and often fatal to ships. Their situation, with regard to the *Bay of Biscay* and the *Atlantic*, is such, that they lie open to the swells of the bay and ocean, from all the south-western points of the compass; so that all the heavy seas, from the south-west quarter, come uncontrolled upon the *Edystone Rocks*, and break upon them with the utmost fury. Sometimes, when the sea is to all appearance smooth and even, and it's surface unruffled by the slightest breeze, the ground swell meeting the slope of the rocks, the sea beats upon them in a frightful manner, so as not only to obstruct any work being done on the rock, or even landing upon it, when, figuratively speaking, you might go to sea in a walnut shell. That circumstances, fraught with danger surrounding it, should lead mariners to wish for a lighthouse, is not wonderful; but the danger attending the erection leads us to wonder, that any one could be found hardy enough, to undertake it. Such a man was first found in the person of Mr. H. WINSTANLEY, who, in the year 1696, was furnished by the *Trinity House* with the necessary powers. In 1700 it was finished; but in the great storm of November, 1703, it was destroyed, and the projector perished in the ruins. In 1709 another, upon a different construction, was erected by a Mr. RUDYERD, which, in 1755, was unfortunately consumed by fire.

The next building was under the direction of Mr. SMEATON, who, having considered the errors of the former constructions, has judiciously guarded against them, and erected a building, the demolition of which seems little to be dreaded, unless the rock on which it is erected should perish with it. Of his works, in constructing bridges, harbours, mills, engines, &c. &c. it were endless to speak.

Of his inventions and improvements of philosophical instruments, as of the air-pump, the pyrometer, hygrometer, &c. &c. some idea may be formed from the list of his writings inserted below.

In his person, Mr. SMEATON was of a middle stature, but broad and strong made, and possessed of an excellent constitution. He had great simplicity and plainness in his manners: he had a warmth of expression that might appear, to those who did not know him well, to border on harshness; but, such as were more closely acquainted with him, knew it arose from the intense application of his mind, which was always in the pursuit of truth, or engaged in the investigation of difficult subjects. He would sometimes break out hastily, when any thing was said that was contrary to his ideas of the subject; and he would not give up any thing he argued for, till his mind was convinced, by the deducement of facts, before unknown to him, and by sound reasoning. In all the social duties of life, Mr. SMEATON was exemplary; he was a most affectionate husband, a good father, a warm, zealous, and sincere friend, always ready to assist those he respected, and often before it was pointed out to him in what way he could serve them. He was a lover and an encourager of merit wherever he found it; and many persons now living are in a great measure indebted for their present situation to his assistance and advice. As a companion, he was always entertaining and instructive, and none could spend their time in his company without improvement.

As to the list of his writings; besides the large work above-mentioned, being the History of the *Edystone Lighthouse*, and numbers of Reports and Memorials, many of which were printed, his communications to the Royal Society, and inserted in their Transactions, are as follow:

1. An Account of Dr. KNIGHT's Improvements of the Mariner's Com-
pafs. An. 1750, pa. 513.
2. Some Improvements in the Air-Pump. An. 1752, pa. 413.
3. An Engine for raising Water by Fire; being an Improvement on
SAVARY's Construction, to render it capable of working itself; invented
by M. DE MOURA, of *Portugal*. Ib. pa. 436.
4. Description of a new Tackle, or Combination of Pulleys. Ib. pa. 494.
5. Experiments on a Machine for measuring the Way of a Ship at Sea.
An. 1754, pa. 532.

6. Description

6. Description of a new Pyrometer. Ib. pa. 598.
7. Effects of Lightning on the Steeple and Church of *Lestwithial* in *Cornwall*. An. 1757, pa. 198.
8. Remarks on the different Temperature of the Air at *Edystone Lighthouse* and at *Plymouth*. An. 1758, pa. 488.
9. Experimental Enquiry concerning the natural Powers of Water and Wind to turn Mills, and other Machines depending on a circular Motion. An. 1759, pa. 100.
10. On the Menstrual Parallax arising from the mutual Gravitation of the Earth and Moon, it's Influence on the Observation of the Sun and Planets, with a Method of observing it. An. 1768, pa. 156.
11. Description of a new Method of observing the Heavenly Bodies out of the Meridian. An. 1768, pa. 170.
12. Observations on a Solar Eclipse. An. 1769, pa. 286.
13. Description of a new Hygrometer. An. 1771, pa. 198.
14. An Experimental Examination of the Quantity and Proportion of Mechanical Power necessary to be employed in giving different Degrees of Velocity to heavy Bodies from a State of Rest. An. 1776, pa. 450.

The COMMITTEE of CIVIL-ENGINEERS.

Fellfoot, near Kendal, 30th October, 1797.

GENTLEMEN,

THE advertisement relative to the publication of Mr. SMEATON's works, recalls to my mind a request made from you, through Mr. BROOKE, "that his daughters would assist in furnishing any anecdotes illustrative of "his life and character." And this recollection calls upon me to apologize for the apparent neglect, as well as to account why an office so pleasant could be delayed for a moment. The fact is, Gentlemen, that, however immediate the impulse was to set about it, I soon found, in so doing, the task at once difficult and delicate. .

The public ear, I am afraid, is satiated and fastidious; and the plain anecdotes of a plain man, like him, though interesting to individuals, could awaken little public curiosity, or perhaps, give still less satisfaction when awakened. And, extraordinary as it may seem, his family, probably less than others, are in possession of anecdotes concerning him; for, though communicative on all subjects, and stored with ample, and liberal observations on others; of *Himself*, he never spoke. In nothing does he seem to have stood more single, than in being devoid of that egotism, which, more or less, affects the world. It required some address, even in his family, to draw him into conversation directly relative to himself, his pursuits, or his success. Self-opinion, self-interest, and self-indulgence, seemed, alike, tempered in him, by a modesty inseparable from merit,—a moderation in pecuniary ambition,—a habit of intense application, and a temperance strict beyond the common standard. And, it is owing, perhaps, to this regulation, that, through a course of incessant fatigue, and incredible exertion, from *six years old to sixty*, the multiplicity of business, and pressure of cares, never had power to deaden his affections, or injure his temper.

VOL. I.

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I say,

I say, "*six years old to sixty*," because while in petticoats, he was continually dividing circles and squares; all his play-things were models of machines, which destroyed the fish in the ponds, by raising water out of one into another. At school;—his exercises, in the law, to him not an agreeable destination; his dry, though useful attainments, occupied him through the day;—but mechanics, and his favourite studies, engrossed the chief of every night. So that his mind appears to have endured an incessant exertion through that period.

It was his maxim, "that the abilities of the individual, were a *debt* due to the common stock of public happiness, or accommodation!" This appears to have governed his actions through life; for the claim of society (thus become sacred) his time was devoted to the cultivation of talents, by which he might benefit mankind; and thenceafter, to the unwearied application of them.—

Indefatigable in the pursuits they led to, the public are in possession of all which Nature intrusted to him, or the measure of life allowed.

His friends know well how to appreciate the honest man, who valued them! And what he was in his family, every member of it could speak, if called upon, with equal gratitude, pride, and pleasure!

The arrangement of his time was governed by a method, as invariable as inviolable: for professional studies were never broken in upon, by any one; and these, (with the exception of stated astronomical observations,) wholly ingrossed the forenoon. His meals were temperate, and for many years restricted, on account of health, to *rigid* abstinence, from which he derived great benefit.

His afternoons were regularly occupied by practical experiments, or some other branch of mechanics. And not more entirely was his mind devoted to his profession in one division of his time, than abstracted from it
in

in another. *Himself* devoted to his family with an affection so lively, a manner at once so cheerful and serene, that it is impossible to say, whether the charm of conversation, the simplicity of instructions, or the gentleness with which they were conveyed, most endeared his home. A home, in which from infancy we cannot recollect to have seen a trace of dissatisfaction or a word of asperity to any one. Yet with all this he was absolute! And it is for casuistry in education, or rule, to explain his authority; it was an authority, as impossible to dispute as to define.

The command of his feelings, and submission of a temper, naturally warm, to reason and benevolence, were strongly illustrated by a circumstance, (in my recollection,) peculiarly trying to him. It arose from the conduct of a man formerly employed as a clerk, in whom having the highest confidence and esteem, he procured him a similar, though more lucrative, situation in a public office; where he served with a fidelity which in time promoted him to a station, of high trust and responsibility, (my father being bound, jointly with another gentleman, for his conduct, in a considerable sum.) It were needless to say by what degrees in error this man fell; it suffices, that at last he forged a false statement, to meet the deficiency; that he was detected, and given up to justice. The same post brought news, of the melancholy transaction; of the man's compunctions and danger; of the claim of the bond forfeited; and of the refusal of the other person to pay the moiety!—Being present when he read his letters, which arrived at a period of Mrs. SMEATON's declining health, so entirely did the command of himself second his anxious attention to her, that no emotion was visible on their perusal; nor, till all was put into the best train possible, did a word, or look, betray the exquisite distress it occasioned him. In the interim, all which could soothe the remorse of a prisoner, every means which could save, (which did, at least from public execution,) were exerted for him, with a characteristic benevolence, "active and unobtrusive."

The disinterested moderation of his pecuniary ambition, every transaction in private life evinced; his public ones bore the same stamp: and after his health had withdrawn him from the labours of his profession, many instances may be instanced by those, whose concerns induced them to press importunately for a resumption of it: and when some of them, seemed disposed to enforce their entreaties by further prospects of lucrative recompence, his reply was strongly characteristic of his simple manners and moderation. He introduced the old woman, who took care of his chambers in *Gray's Inn*, and shewing her, asserted, "that her attendance sufficed for "all his wants." The inference was indisputable, "for money could not "tempt that man to forego his ease, leisure, or independence, whose "requisites of accommodation were compressed within such limits!"

Before this, the Princess DE ASKOFF made an apt comment upon this trait of his character; when, after vainly using every persuasion to induce him to accept a *carte blanche* from the EMPRESS of RUSSIA, (as a recompence for directing the vast projects in that kingdom,) she observed, "Sir, you are "a great man, and I honour you! You may have an equal in abilities, per- "haps; but in *character* you stand single. The *English* minister, Sir ROBERT "WALPOLE, was mistaken, and my sovereign has the misfortune to find "one Man who has not his price!"

Early in life he attracted the notice of the late DUKE and DUCHESS of QUEENSBURY, from a strong resemblance to their favourite GAY, the poet. The commencement of this acquaintance was singular, but the continuance of their esteem and partiality lasted through life.—Their first meeting was at *Ranelagh*, where, walking with Mrs. SMEATON, he observed an elderly lady and gentleman fix an evident and marked attention on him. After some turns they at last stopped him, and the DUCHESS (of eccentric memory) said, "Sir, I don't know who you are or what you are, but so strongly do "you resemble my poor dear GAY, we *must* be acquainted; you shall go "home and sup with us; and if the minds of the two men accord, as do "the countenance, you will find two cheerful old folks, who can love you
"well;

"*well, and I think, (or you are an hypocrite,) you can as well deserve it.*"—The invitation was accepted, and, as long as the Duke and Duchess lived, the friendship was as cordial as uninterrupted; indeed, their society had so much of the *play* which genuine wit and goodness know how to combine, it proved to be, among the most agreeable relaxations of his life.—A sort of amicable and pleasant hostility was renewed, whenever they met, of talent and good humour; in the course of which, he effected the abolition of that inconsiderate indiscriminate play, amongst people of superior rank or fortune, which compels every one to join, and at their own stake too.—My father detested cards, and his attention never following the game, played like a boy. The game was *Pope Joan*, the general run of it was high, and the stake in "*Pope*" had accidentally accumulated to a sum more than serious. It was my father's turn by the deal, to *double it*, when, regardless of his cards, he busily made minutes on a scrap of paper, and put it on the board. The Duchess eagerly asked him what it was? and he as coolly replied; "Your Grace will recollect the field in which my house stands may be about 5 acres, 3 roods and 7 perches, which, at thirty years purchase, will be just my stake, and if your Grace will make a Duke of me, I presume the winner will not dislike my mortgage."—The joke and the lesson held alike their weight; they never after played but for the merest trifle.

The manly simplicity of deportment to his superiors, however; was alike free from pretension and servility; and an invariable consideration and kindness to his inferiors, produced a singular sentiment of veneration, in those who served him.

He always apprehended the stroke which terminated his life, as it was hereditary in his family; he dreaded it *only* as it gave the melancholy possibility of out-living his faculties, or the power of doing good: to use his own words, "*lingering over the dregs, after the spirit had evaporated!*"

When this really did happen, the composure, with which he met it; his anxious endeavour to soften any alarm to his family; his resignation to the event; and his dignified thankfulness on finding at last, his intellect was spared,

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were every way worthy of himself. Still his invariable wish was, "to be released!"

In the interim, (six weeks) all faculties, and every affection, were as clear and animated as at any period of his life. His memory was tenacious, and his ingenuity as active to relieve the inconveniencies of his then situation, as such situation gave what he termed, trouble to those about him. —

He expressed a particular desire and pleasure, in seeing the usual occupations resumed; and reading, drawing, music and conversation excited the same interest, the same cheerful and judicious observations as ever.

He would sometimes complain of his own slowness, (as he called it,) of apprehension, and then would excuse it with a smile, saying, "It could not be otherwise, the shadow *must* lengthen, as the sun went down!" There was no *slowness* in fact to lament; for he was as ready at calculations, and as perspicuous in explanation, as at any former period. Some phenomena respecting the moon were asked him one evening, when it actually shone bright, full into his room. When he had spoke fully on them, his eyes remained fixed upon it with a most animated attention, to us impressive; then turning them, on us with benignity, observed, "How often have I looked up to it with inquiry and wonder! To the period, when I shall have the vast and privileged views of an *HIEREFTER*, and all will be comprehension and pleasure!"

Shortly after, the end he had through life desired, was granted; the body gradually sunk, but the mind shone to the last; and in the way good men aspire to, he closed a life, active as useful, amiable as revered!

MARY DIXON.

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R E P O R T S, &c.



QUESTIONS proposed by the Magistrates and Town-Council of *Dumfries* to the consideration of MR. SMEATON. October, 1760.

1st. **W**HAT is the easiest and most effectual method for preserving the town's grounds of *Kingbolme* from the future encroachments of the river?

2d. How can the navigation of the river *Nith* be most easily improved, from *Kingbolme* to *Kelton*, and the channel rendered less precarious than it is at present?

3d. It is desired that MR. SMEATON may visit the works carried on in the under part of the river, opposite to the Merse grounds of *Netherwood*, *Cargin*, and *Lagball*; and, upon considering the course of the river, and the situation and extent of these works, to give his opinion how far the navigation of the river will be bettered or injured by such works; and what amendments or alteration of them are necessary for preserving the navigation entire? And in case such works are attempted to be made by other heretors, what orders ought the Magistrates and Town-Council to give thereanent, as being guardians of the public navigation of this river; and how many feet or fathom broad ought the channel to be kept free at those places?

In case it shall be thought proper or necessary that any of the works already erected ought to be destroyed, whether should the stakes be pulled up or knocked down, equal to or below the surface of the ground where they now are; and what ought to be done with such parts of the works as are of stone?

EBEN. HEPBURN.
JOHN DICKSON.
WM. CLARK.

ANSWERS to the questions proposed by the Magistrates and Town-Council
of *Dumfries*, for the consideration of J. SMEATON.

HAVING carefully examined the course of the river *Nith* and the banks thereof, from *Dumfries* to *Kirkconnel* on the West side, and from *Kelton* to *Dumfries* on the East, both upon the flood and ebb of a spring tide, I am of opinion as follows :

Answer to question 1.—Where the banks, by the undermining of the water, tumble down, I would advise them to be sloped as low down as where the water begins to act, and to defend the foot of the slope by rows of stakes, single or double, according to the violence of the water's action, placed in a direction parallel to the bank, with binders to confine down a lay of fascines pointing towards the water. The slope of the bank must not be greater than to incline five feet backward for every yard of perpendicular height ; the surface of this slope to be soddied, sown with hay seeds, or otherwise grassed over as far as the grass will grow, and the remainder covered with gravel, laid partly upon the fascines. The directions of the rows of stakes ought to be suited to the direction of the water, attempting as much as possible a right line or fair curve, avoiding as much as possible all sudden turns and irregularities.

Answer to question 2.—The channel of the river *Nith* has so many sudden turns and irregularities, that the tide spends itself among the sinuosities of the river, and in filling up wide spaces above, after having passed through narrower below, and is thereby prevented from mounting to so great a perpendicular height as it would otherwise attain, in the upper parts of the river near *Dumfries* in case the course was more straight, and had a more regular contraction ; and this disadvantage is still the greater, as the space of time occupied by the tide of flood is so short, that it begins to ebb below, before the loops of the river, in the superior part, have time to fill to the level that the surface had been at in the lower, at high water. The navigation, therefore, seems incapable of any great improvements at any moderate expence, otherwise than by cutting a navigable canal, with proper locks and other works upon it, which can be done for much less than it would cost to make the river itself tolerably regular. But the way to prevent it from growing worse than it now is, must be by hindering it from becoming still more crooked, and growing still more wide above than below, giving as free a passage as possible to the tide of flood, especially in the most contracted places. Whatever contributes to this end tends to preserve it ; whatever has a contrary effect must be a detriment to it.

Answer to question 3.—In visiting those grounds and works, I observed as follows. That *Cargin* Merse being situated on the concave side, or in the very bottom of a considerable

siderable loop of the river, the direction which the current receives from the superior grounds, on tide of ebb, and from the inferior, on tide of flood, both strongly tend to carry away the land of *Cargin* Meise, and thereby to render the loop still deeper: I am therefore of opinion, that the jettys and works there constructed, in as much as they contribute to prevent this loop from growing deeper, that is, the river from growing more crooked, they thereby contribute to the benefit of the navigation. But I am of opinion, that those jettys have been advanced too far into the river, whereby the course of the water has, in that part, been too much contracted; and also that, by being placed across the direction of the stream, they have contributed to hinder the free passage of the tide of flood, which would of consequence not fill the upper part of the river to so great a perpendicular height, as has been already mentioned. However, as those jettys have in some measure answered one good purpose, viz. that of preventing the river from falling into a deeper loop in that place, and as it might be of dangerous consequence to disturb the body of sleet there gathered, by totally rooting up those jettys, I am of opinion, that such of the jettys as run across, or intercept the current, should be levelled with the present surface of the sleet, which may be done either by driving down or sawing off the stakes. As to the jettys that have been formed on the *Netherwood* side, as they don't seem to have contributed to save the land, or to have answered any one purpose whatsoever, nor do they seem to produce any other effect than that of contracting the river in this, the otherwise narrowest part, and that of intercepting the current on tide of flood, both which, considering the large wide bay just above, and the various meandrings still higher, together with the smallness of the time that the tide of flood acts at this place, I am of opinion, that those jettys are very prejudicial to the navigation, and therefore think, that all of them, whether of wood or stone, should be pulled up, or otherwise levelled with the present bed of the river on which they stand. As to the jettys and works which have been raised upon the Meise grounds of *Lagball*, such as are contiguous to those of *Cargin* should be served in the same manner as has been mentioned concerning those of *Cargin*; but as to the rest, they are either so inconsiderable, or so placed, as to produce no sensible effect on the navigation. With respect to future works for preserving or gaining of land, provided they are so contrived as to shorten the course of the current, leaving the channel of the river of such a width, as to be wider than the medium width of half a mile above, and narrower than the medium width for half a mile below; at the same time carrying the weir fence, or advanced work, parallel to the natural direction of the current, reducing it, as near as may be, to a right line or fair curve, without sudden elbows and irregularities; laying also the banks or interior works smooth, and sloping, so as not to catch hold of and entangle the current of the tide of flood: I am of opinion, that all such works ought to be encouraged, as being advantageous to the navigation of the river.

QUESTIONS offered by ROBERT MAXWELL of *Cargin* to the consideration of Mr. SMEATON.

THE Merse grounds of *Cargin* belonging to MR. MAXWELL, are situated on the west side of the river *Nith*, opposite to the Merse belonging to Mr. JOHNSTON, of *Netherwood*, on the east side of the river.

The Merse of *Cargin* for many years had been greatly injured by the river, until MR. MAXWELL raised weirs, or small creals, for defending his property from future encroachment. MR. JOHNSTON, late of *Netherwood*, made works of the same nature on his side, which extend a considerable way higher up the river than MR. MAXWELL's, and opposite to works of the like construction erected on the other side by Mr. CORRIE, an heretor adjoining to *Cargin*, on the north or upper side.

While these works were carrying on, the Town Council (as guardians of the navigation of the river) interposed their authority, and, on a visitation thereof, appointed certain parts of the works, on both sides, to be removed, as being prejudicial to the public navigation. This order having been intimated to the whole heritors concerned, they agreed to comply therewith, and became bound in writing to remove the works pointed out as being so injurious. Accordingly MESSRS. MAXWELL and CORRIE did remove such parts of their works as were ordered, and fixed posts or pearches on what remained, for the direction of mariners. The other heretor, MR. JOHNSTON, did not remove a stick or stone of his; on the contrary, his heir and successor is now insisting to have the whole of MR. MAXWELL's works removed, as being hurtful to his, Mr. JOHNSTON's, property, and to the public navigation.

It is therefore desired that MR. SMEATON will view the works on both sides, and, upon considering the situation and extent of them, to give his answer to the following questions.

1st. How far were these works necessary for preserving the Merse of *Cargin*; and how can they be further secured, without injuring the navigation of the river, or the private property of others?—In considering this question it is to be observed, that by the situation of the opposite grounds of *Netherwood*, and the higher works thereon, which extend far into the channel, the force of the land flood and ebb tide, as well as the current of the flowing tide, is thrown with much violence on the bosom of *Cargin* Merse, which has nothing but these

these works to repel the force of it; so that MR. SMEATON will please to consider what would have been the natural consequence had such work not been made.

Question 2.—How far are the works on *Cargin* side prejudicial to public navigation? And please also consider whether works of this kind, raised in defence of private property, are illegal and unprecedented; and whether they tend to hurt public navigation, and injure the private property of an opposite heretor.

QUESTIONS offered by ROBERT MAXWELL, of *Cargin*, anent his work on the side of the river *Nith*, to the consideration of MR. J. SMEATON.

IT is desired that MR. SMEATON, in visiting the river, will view and consider the course of the river, the floods and tide, and the situation of the grounds and works constructed thereon, upon the Merfes of *Cargin* and *Netherwood*, and give his answers to the following questions.

1st. Whether from the course of the river, and the situation of the opposite ground, the Merfe of *Cargin* is exposed to the force of the land flood and ebb tide, and also to the current of the flowing tide; and if works were not therefore necessary, for defending *Cargin* Merfe from the future encroachments of the river?

2d. Whether the work already erected on *Cargin* Merfe can hurt or prejudice the opposite Merfe of *Netherwood*; and whether these works can be deemed illegal and unprecedented, as being injurious to the opposite grounds?

3d. How can these works be secured or improved, in the easiest and most effectual manner, for preserving *Cargin* Merfe, without injuring public navigation, or the private property of neighbouring heretors?

ROBERT MAXWELL.

ANSWER

ANSWERS to the Questions offered by ROBERT MAXWELL of *Cargin*, anent his Works on the side of the River *Nith*, by JOHN SMEATON.

Answer to Question 1st.

CARGIN Merse laying in the bottom, or most concave part, of a considerable loop of the River *Nith*, is by its situation exposed to the principal action of the flood and ebb tides, and also to that of the land floods; and the natural soil being of a very loose nature, artificial works were absolutely necessary, for the defence thereof from future encroachments of the river, as without this, the natural effect of the currents would be, to make this loop of the river still deeper, by carrying away the soil of *Cargin Merse*.

Answer to the 2d question.—As *Cargin Merse*, notwithstanding what has been done, is still on the concave side of a deep loop of the river, the principal force of the current is still exerted on that side; and as the opposite grounds lay upon the convex side, they cannot be sensibly affected thereby; and those above, or below this concavity, are at too great a distance, to be thereby affected. Works for this purpose are frequently made, and if not advanced further than what has been known to have been firm ground in the memory of man, I apprehend cannot be deemed illegal; but this part of the question more properly belongs to the laws.

Answer to the 3d. question.—By making the weirs parallel to the direction of the current, so as to make, as much as possible, a right line or fair curve, and sloping the banks, covering the same with fascines and gravel, except on such places as they can be grassed over.

Austhorpe, 28th November, 1760.

J. SMEATON.

On the water-works at *Halifax*.

To Mr. SIMPSON.

S I R,

ENCLOSED you have a sketch of the method which I would propose for laying of the pipes of the intended Water-works at *Halifax*, and an estimate referring thereto, which I hope will be near the matter, having spent some time in the consideration and forming thereof; however, I would not wholly rely upon my own judgment, but desire that those papers may be overlooked and considered by my ingenious friend JOSEPH KNIGHT, whose natural sagacity and acquirements in these kinds of affairs will, I am persuaded, lead him to discover and point out such oversights and mistakes as I may have been guilty of, notwithstanding the care I have taken; and I must take this opportunity of desiring, that, though the Gentlemen have thought proper to consult me on this occasion, I may not be considered as any bar to his merit, but rather as jointly concerned.

It may not be amiss, however, to point out the general principle upon which I have conducted myself; and, in the first place, as the town lays very unequal in point of level, and of consequence, a very great perpendicular pressure will lay upon the pipes, especially towards the lower parts, I have endeavoured to avoid the additional expence, that naturally would arise from proportional encrease of thickness, by taking advantage of such circumstances in the situation, as have a tendency to relieve the disadvantages thereof; and, with this view, I have assigned the bores of the pipes in general considerably less than I should have done, in case the town had been more upon a level, because the declivity has a tendency to force the water through the pipes with greater velocity, and make them give as much water through a given orifice, as would be done by a larger pipe more upon a level, and with a lesser pressure upon it.

2dly. Considering that the supply will come from above the head of the town, and that the pipe of conduct, at its first entrance into the town, must carry all the water necessary for the supply of the whole, but that in going lower down it has only the water to convey for such parts as lay still lower; of consequence, the necessary bore of the pipe of conduct will grow less and less the further and lower it goes; but as it is a certain principle in hydraulics, that pipes become stronger in proportion as their diameters are less, when the thickness of the shell of the metal is the same, it follows, that if their bores are diminished in proportion as their perpendicular pressure is increased, the smaller pipe will be as able to sustain its weight of water as the larger will be to sustain the pressure peculiar thereto;

thereto : for these reasons, instead of adding to the weight of metal as we go lower down, I have proposed the same thickness for the main all the way, and by diminishing the diameter, and consequently the weight, have added the necessary strength ; by which advantage a great weight of metal will be saved, without injury to the main design. As to the branches, I have proportioned their thickness to the thickness of that part of the main which is upon the same level, regard being had to the difference of their bores ; by these means every part of the system of pipes will be equally strong, with respect to the stress that will come upon it. I don't mean, however, that every part is adjusted with a mathematical exactness ; for as I have allowed every part to be considerably stronger than what may be barely called sufficient, that would be not only unnecessary, but by making every yard of pipe of different bore and thickness, would be more unreasonably troublesome in the execution. That that part of the main which lays between the reservoir at the *Gibbet*, and the back street, I have supposed of the same bore and thickness all the way, for the ease of calculation ; but, in reality, I propose it to be considerably wider towards the reservoir, yet, as the pressure diminishes that way, it can be done with the same metal as the calculation supposes.

3dly. Considering, likewise, the inequality of the ground in another view, in case there should be, at any time, any defect in point of quantity furnished to the reservoir for the supply of the whole town, it is evident that the lower parts of the town would be first supplied, because the water will naturally run down hill, and accumulate in the lowest parts first, by which means the lower parts would be well supplied, when the upper parts were partially, or scarce at all supplied : and even when the reservoir would furnish as much water as the pipes could take, as the water would issue with much greater velocity from the lower cocks than from the higher ; should many of the lower cocks be open together, this would still abate the issuing of the water from the higher, and especially those at a distance from the main, so that while the lower cocks were kept running in this manner, the upper ones would be but faintly supplied ; for remedying of which defects, as well as others that would accrue from the sensible effects of the leakage and waste of all the cocks in the town at once, I propose to part the town into two divisions, the upper and the lower, to receive the water alternately : the upper division to consist of all the streets above the Hall end, and the lower division of all below, which will be done by placing a stop-cock upon the main at * ⊕, and three others at the three principal branches at ⊕ A, ⊕ B, and ⊕ C ; by which means, the * cock being shut, and A, B, and C open, the upper division will be served alone : on the contrary, the cocks A B C being shut, and the * cock open, the lower division will be served, and no part of the upper. And here it must be remarked, that I propose the two streets, called

called the bottom of *Gibbet-lane* and the *Swine-market*, to be served out of the branches p r, p m, and not from the main A B, B C; for otherwise, those two streets, with the upper branches dependant thereon, would be perpetually supplied, whereas the supply of every other part of the town would be intermitted, and consequently the distribution unequal.

The equality proposed hereby might, perhaps, be still greater, in case the town was divided into more divisions than two; but as the scheme would be embarrassed with a greater number of branches and stop-cocks, I was unwilling to destroy its simplicity for trifling advantages. Perhaps the division that I have proposed may not consist of an equal value of water-rents; but as this may be adjusted by proportioning the time that each division shall receive the water, I would rather propose this method of preserving the equality, than by taking any other point of division, which, as the town is shaped, I think would not be so convenient.

4thly. Respecting the method of conveyance of the water from the spring to the reservoir; though I am still of opinion it may effectually be done in a gutter lined with clay and gravel; yet, considering that this gutter must be covered, and well secured from evaporation and diversion, I have, upon second thoughts, (at least for the sake of coming to an estimate) supposed this conveyance to be in wooden pipes of four inches bore, which there is no doubt will answer, and not give the water any ill taste, as the descent from *Broadby Laitb* to the *Gibbet* is great enough to give the water a rapid current, consequently its time of continuance in the pipes will probably not exceed half an hour.

5thly. I have only further to observe, that I have not included the purchase in my estimate, which, added to the amount thereof, will make a sum much beyond what seemed to be imagined when I was at *Halifax*; and, on this account, I have been the more minute, and have inclosed a copy of the amount of each particular part of the lead-work, that in case I have inserted or omitted any street which ought to have been otherwise, a proper correction may be made, and also that the whole may be submitted to examination, from whence I flatter myself it will appear that the matter is not exaggerated. And I am, with the utmost respect to the gentlemen promoters of this scheme,

S I R,

Your most humble servant,

J. SMEATON.

P. S. Please to tell my friend, Mr. STANSFIELD, that the improvements I supposed might be made in fulling as well as other mills, when this matter came in question on the *Culder*, is no longer a matter of theory; and, contrary to the determination of Mr. BANKS, *that a fulling-mill is a machine so simple, that it is not capable of any farther improvement*, a fulling-mill that has been erected from one of my plans, in dry times, goes with less than a quarter of the usual quantity; and in freshes goes with 3 feet 8 inches tail water; though the greatest difference between head and tail water, when the last is most down, in dry seasons, never exceeds 4 feet 6 inches.

ESTIMATE for the Water-works at *Halifax*.

	£.	s.	d.
To expences in walling and securing the spring head, - - - - -	20	0	0
To piping from <i>Broadby Lash-spring</i> to the <i>Gibbet</i> , being two miles, to be wood pipe four inches bore, laying and compleating, at 5 s. per yard, - - - - -	880	0	0
To erecting a water-house and reservoir near the <i>Gibbet</i> , - - - - -	200	0	0
To 653 cwt. of lead piping in the main, leading from the reservoir to <i>Smithy Staks</i> , solder-work, laying, and making good the streets, at 1 l. 4 s. per cwt. - - - - -	783	12	0
To 931 cwt. in the branches at ditto, - - - - -	1117	4	0
To four large brass stop-cocks and a valve, at 4 l. each, - - - - -	20	0	0
	<hr/>		
	3030	16	0
To unforeseen expences, at 10 per cent. - - - - -	303	0	0
	<hr/>		
	3333	16	0
	<hr/>		

London, 14th February, 1761.

Place.	Bore.	Thick- ness.	Length.	Weight.
			Ch. L.	lbs.
* A	3½	⅜	12 10	25,555
AB	3½	⅜	2 80	5,914
BC	3½	⅜	5 85	11,624
CD	3	⅜	5 30	9,864
DE	2¾	⅜	3 13	5,433
EF	2½	⅜	3 18	5,123
FG	2¾	⅜	3 10	4,604
GH	2	⅜	3 68	5,005
			39 14	73,122

N. B. The Mark * is sup-
posed to be placed at the
Gibbet.

C. qrs. lbs.

73,122 = 652 3 14

Branches.				
Aa	2½	⅜	4 81	5,714
ab	2½	⅜	2 52	2,223
Bb	2½	⅜	6 00	5,292
Cb	2¾	⅜	7 23	7,852
bcd b	2	⅜	13 00	7,937
ef	1¾	⅜	1 92	1,042
ghi	1¾	⅜	8 62	6,141
kl	2	⅜	2 76	2,201
lm	1¾	⅜	5 00	3,562
no	1½	⅜	2 85	1,354
pq	1¾	⅜	4 00	2,171
rs	1½	⅜	1 75	831
pr	2¾	⅜	2 90	2,558
rm	2¾	⅜	6 00	6,516
tv	2¾	⅜	3 20	3,475
vw	2	⅜	8 00	6,378
vx	1¾	⅜	4 10	2,921
vE	1½	⅜	5 10	3,200
Dy	2¾	⅜	3 00	3,870
yz	2	⅜	5 30	5,215
RV	1½	⅜	1 50	941
ST	1½	⅜	2 60	1,632
ENOG	1¾	⅜	9 20	8,115
QP	1½	⅜	2 40	1,506
HM	1½	⅜	3 60	2,808
HI	1¾	⅜	2 17	2,282
IKKL	1½	⅜	7 00	6,528
			126 53	104,265
			165 67	177,387

C. qrs. lbs.

104,265 = 930 3 21

177,387 1583 3 7

PROPOSALS for building an engine for raising water 11 feet from the well or reservoir, into the piece of water in the gardens of Her Royal Highness the DOWAGER PRINCESS OF WALES, at *Kew*, to be worked by one large or two light horses.

THE following things are supposed to be done at the expence of Her Royal Highness: The drain or gutter, leading from the engine to the *Chinese* house to be lowered four feet; the ground to be cleared and levelled for the engine to stand upon; the earth to be wharfed up with brick-work; the well cleaned, and the brick-work repaired, where necessary; and, in case it is thought expedient to underpin the groundfill of the shade with brick, the materials to be led from the river to the place, and the labourers to assist in lifting and digging what may be required during the setting up.—The engine to work with an *Archimedes* screw, 2 feet 8 inches diameter, and 24 feet long; the shade for the horses to be 30 feet from out to out, and the mean diameter of the horse track 24 feet.

This engine to raise 1200 hogsheads in four hours, with one large horse or two light ones, such as have heretofore been used.

A small pump, to be worked occasionally by the engine, for raising water from the gutter to the cistern, in the kitchen garden.

The whole of the machinery and frame-work thereof, with the shade for the horses walk, and a cover from the screw, with a cistern and sluice at the foot thereof, to be completed in the most substantial and workman-like manner, for the sum of one hundred and fifty pounds.

The REPORT of JOHN SMEATON, Engineer, concerning the practicability, &c. of a navigable canal from *Wilden* ferry, in the county of *Derby*, to *King's Bromley* common, near *Litchfield*; and from thence in several branches, the first leading to *Longbridge*, near *Burlem*, the second to *Newcastle under Line*, the third to the city of *Litchfield*; and the fourth to the river *Tame*, at or near *Fazeley* bridge, near *Tamworth*, all in the county of *Stafford*, as projected by MR. JAMES BRINDLEY, Engineer.

HAVING, in company with Mr. BRINDLEY and Mr. HENSHALL, land surveyor, in the month of November, 1760, carefully viewed and considered the tracts of ground through which the canal abovementioned and its branches are proposed to pass, and compared the same with the plans and levels produced by Messrs. BRINDLEY and HENSHALL; and also viewed the course of the rivers, (*Trent* and *Tame*) as well as the several brooks, streams, water-courses, and whatever else seemed principally to relate to the abovementioned project, it appears to me as follows:

1st. That the waters that are or may be collected into the brooks, at the head of the proposed canal and its several branches, are respectively sufficient to supply the same with water; and that the canal and its branches, as projected by Mr. BRINDLEY, are practicable, and may be executed at the several expences contained in an estimate bearing the same date as this report.

2d. That as the river *Trent* appears to have few pools naturally navigable, in proportion to its extent, and those of no great length, but on the contrary abounds with shoals, is in many places very winding, in general runs in a shallow channel, and is subject to continued floods; in consequence a new canal will answer the purposes of a navigation, in the present case preferable to carrying the same more generally through the mother river, and which, for a great part of the tract in question, is impracticable at any tolerable expence.

3d. That, in particular, the present navigable part of the *Trent*, between *Wilden* ferry and *Burton*, is so much obstructed by shoals and scours, that the purposes thereof would be much more effectually answered by the canal projected by Mr. BRINDLEY.

4th. That the tracts of ground through which the canal abovementioned and its branches are proposed by Mr. BRINDLEY to pass, are well chosen, and for the greatest part well adapted by nature for such a purpose, and as little injurious to private property as the nature of such a work will admit of; Mr. BRINDLEY having judiciously designed the course thereof to pass through a great number of level commons and waste grounds, and, in general, through the most barren lands that could be found in any wife to agree with the course thereof.

5th. That a branch from the canal to *Longbridge* may be conducted upon a dead level from near the town of *Stoke* to the town of *Newcastle*, as laid down in the plan.

6th. That a canal from *King's Bromley* common may be conducted up the valley of *Litchfield Brooks*, to the city of *Litchfield*, but at a very moderate charge, to the tail of *Stow* pool.

7th. That a canal being conducted upon a level from some proper point of the main canal, at or near *King's Bromley* common, the same will meet the valley of the *Tame*, at or near *Fazeley* bridge; and by inverted locks a communication may be formed, and the navigation may be carried by that river to the borough of *Tamworth*, the waters being pounded up thither by the mills at *Tamworth*.

8th. That the branch of the canal, proposed to be carried to *Longbridge*, is capable of being extended, so as to join the navigable river that falls into the west sea; for it is but a little above two miles from *Longbridge*, to a meadow which lies between two hills near *Flarecastle*, in which meadow the waters that run into the west sea divide from those that make their way into the east, and which therefore may be called the point of partition. The grounds between *Longbridge* and this point lie with a gentle declivity, and, according to a level taken by Mr. HENSHALL, this point of partition is elevated above that of *Longbridge* a little more than 90 feet; but as one third part of this ascent lies within a quarter of a mile of the summit, and as the ground there appears to be suitable, a considerable part of this ascent may be avoided, by a deep cut through the summit, which will be of a moderate length, as the ground seems of the same quality, and to fall away much in the same manner on the west side as on the east; and as, according to the report of those who know the grounds, particularly the meadows on the west side, are nowhere interrupted by rocks, or other remarkable obstructions, a canal is by consequence as practicable from the point of partition westward, as it is from the same point eastward; and the distance is not near so great to the navigable rivers on the west, as

on the east. It only remains that probable means be shown of supplying this additional canal at the point of partition with water; for if this is done, the lower parts will be supplied of course: In respect whereof it must be observed, that the point of partition lies greatly under the level of the adjacent hills, and consequently the springs issuing from such hills may be conducted thither, and all the water upon the more elevated grounds may be intercepted for several miles round, in order to supply a reservoir in a proper place, above the level of the point of partition. These springs will be further assisted by water issuing from the coal-pit drains that now are, and hereafter will probably be multiplied, as the grounds hereabouts abound with coal, the greatest part of which is at present ungot; but should all these resources, in a dry season, prove too little, the navigation may be supplied with water by the help of a fire engine, to return the waters from a lower level, where the collection of springs may at all times be sufficient; so that the water may be used as many times over as may be needful.

9th. That from the best information it appears, that the present navigation between *Wilden* ferry and *Gainbrough* is much obstructed by shoals and scours, insomuch that in several places, in the common state of the river in dry seasons, there is not above 8 inches depth of water, and that at such times, without the aid of flashes from Kings mills upon the *Trent*, and the lowest mills upon the *Derwent*, the navigation would then be impracticable.

10th. That, for these reasons, the purpose of the canals before mentioned will not be fully and completely answered, without an amendment of the navigation between *Wilden* ferry and *Gainbrough*, either by an extension of the main canal from *Wilden* ferry to the tide's way, or by some other means that may effectually answer the purpose; nevertheless, I am of opinion,

11th. That the purpose of the canals already mentioned will in good part be answered, even should the obstructions of the navigation between *Wilden* ferry and *Gainbrough* remain as they are; for, notwithstanding those obstructions, a large quantity of goods is navigated up this part of the river with advantage, and if a canal is completed, on the present plan, to *Wilden*, it will be still better worth while to conquer the difficulties attending this part, in order to get into a clear and complete navigation, that will carry goods, without obstructions, into the heart of the kingdom, according to the printed plan; and even across the kingdom, if the scheme should take place in its full extent; and whenever that is the case, it is not to be doubted but means will be found of rendering the navigation between *Wilden* ferry and *Gainbrough* equally perfect with the rest,

12th. In order therefore that the boats which at present navigate upon the *Trent* may navigate freely upon the new canal, I am of opinion with Mr. BRINDLEY, that the canals ought to be about 8 yards wide at the water line; and that the new canal may be of a suitable depth, when the obstructions below *Wilden* are removed, the same ought to be 2 feet 6 inches deep of water upon the fording-places, which ought to be shoalest, and 3 feet or 3 feet 6 inches in other places, to allow for mud, and sufficient freedom for the vessels; and this depth will be of advantage, notwithstanding the want of depth of water below, because the loading of two vessels from *Gainsbrough* may be put into one at *Wilden*, and the loading of two vessels at *Wilden* brought in one from above.

13th. That the lock gates being made water tight, as they are capable of being made, no mill can be deprived of any water. Farther, that one lockful to each boat, which on exact calculation is found to be a very inconsiderable quantity, in proportion to what is necessary to work a mill for 24 hours; the evaporation from the surface of the canals, and leakage through the banks into the back drains, scarcely deserve mention, with respect to their effect on the mills. As to fisheries, they cannot in any wise be affected, because the waters in the canals being nearly stagnant, and closed by the lock gates, no fish can pass either way.

14th. That the publick road being supplied with sufficient carriage bridges, the water courses with underground passages, the communication between commons and private properties by a sufficient number of fording-places, well paved and sloped, and no where above 2 feet 6 inches deep, and the banks, whenever the water of the canal is even with or above the natural soil, to be furnished with sufficient back drains, to convey any leakage of the water that may happen, to its proper and natural place of discharge; I say, things being thus provided for, public and private roads, all necessary communications between grounds and water courses will not only be preserved, and the grounds themselves freed from damage, but, on the other hand, many lands will be greatly benefited, by having plenty of good water for cattle, &c.

Austhorpe, 11th July, 1761.

J. SMEATON.

General ESTIMATE for making the canals and works for compleating the navigation and branches referred to, in Mr. SMEATON's report, upon principles of estimation settled between Messrs. SMEATON and BRINDLEY.

	£.	s.	d.
1st. To making the main canal from <i>Wilden Ferry</i> to <i>King's Bromley</i> Common, being in length 25 miles, the perpendicular ascent 110 feet, with 19 locks thereon, - - -	32,054	10	0
2d. To making the great western branch, from <i>King's Bromley</i> Common to <i>Longbridge</i> , between <i>Burlem</i> and <i>Newcastle under Line</i> , being in length 30 $\frac{1}{4}$ miles, perpendicular ascent 166 $\frac{1}{4}$ feet, with 28 locks thereon, - - -	45,334	15	0
3d. To the small branch out of the last, proceeding from <i>Stoke</i> to <i>Newcastle</i> , being in length 3 $\frac{1}{2}$ miles, upon a dead level, without a lock, - - -	3,355	6	0
4th. To making the <i>Litchfield</i> branch, from <i>King's Bromley</i> Common to the tail of <i>Storvool</i> near <i>Litchfield</i> , being in length 2 $\frac{1}{2}$ miles, perpendicular ascent about 18 feet, with 3 locks thereon, - - -	3,225	9	0
5th. To compleating the above into <i>Litchfield</i> mill pool, being about half a mile, and perpendicular ascent about 30 feet, with 5 locks thereon, - - -	3,029	18	0
6th. To making the <i>Tamworth</i> branch, from <i>King's Bromley</i> Common to <i>Fazeley Bridge</i> near <i>Tamworth</i> , being in length 10 miles, upon a dead level, without a lock, - - -	9,431	12	0
7th. To compleating the above by a cross canal into the river <i>Tame</i> , being in length half a mile, perpendicular descent 16 feet 10 inches, with 3 locks thereupon, - - -	1,775	12	0
	<hr/>	<hr/>	<hr/>
	102,198	2	0

Ausborpe, 11th July, 1761.

J. SMEATON.

THE RIVER WEAR.

The REPORT of J. SMEATON, concerning the situation of the first lock upon the river *Wear*.

HAVING, in obedience to the order of the Commissioners, at their last meeting on the 2d day of May, 1761, re-examined, as well the situation staked out by me in November last, as the situation lately proposed by the Gentlemen Coal Viewers, who viewed and marked out the same 176 yards higher up the river than the former; and having carefully examined the river in both places, and also at intermediate distances, I am humbly of opinion as follows:

1st. That the erection of a lock at the place marked out by me in November last, cannot have the least tendency to prejudice the coal works underneath; for though the workings underneath are ever so irregular, and though a thrust should have been brought on 2 pillars 30 yards to the north of the lock, yet while those pillars are capable of supporting the river *Wear*, they are capable of supporting the lock. Nor will the placing of a lock there in any wise tend to weaken the body of solid matter interposed between the bottom of the river and the bed of coal; for the fill has been found in the bottom of the staples at 21 feet from the surface of the ground, and it may be necessary to sink the foundation of the lock 24 feet below the same surface; yet as the staples are sunk 18 feet, or thereabouts, more northward than the utmost limits of the lock wall; and since it appears that at the verge of the water, and within the river, the fill lays as low, and in many places much lower than the intended foundation, there does not appear to be any occasion to sink into the fill at all; and yet in case there should be occasion to cut half a foot, or even one foot on the north side, into the fill, by way of bringing the same to a level, (the fill appearing from the staples to rise with the hill towards the north) yet as this will be replaced with matter much more compact and impenetrable to water than the fill itself, it is not easy to conceive that this can in the least prejudice the resistance of a body of matter 12 or 15 fathom in thickness, being so much down to the workings of the 5 quarter coal.

2dly. That it is practicable to build a lock at the place marked out by the Gentlemen Coal Viewers, 176 yards higher up the river than the former; but that such situations will be attended with the following additional disadvantages.

1ft. It appears, that the fill laying at the last mentioned place, at a medium, $1\frac{1}{2}$ feet lower than the foundation of the lock, the carrying the foundation one foot and a half lower than necessary, will not only be attended with a considerable charge, but being a quicksand down to that depth, the drainage of the water, and securing the sides of the lock-pit till the bottom is finished, will be much more difficult and expensive also. And lastly, as there will be a necessity of making a channel for the passage of the vessels on the north side, into the lock, from the tail of the lock, as proposed in its former situation, it will therefore be necessary to dredge the whole distance of 176 yards; and not only that, but to secure the side of the channel next the river with a proper fence, to prevent its being filled with the silt of the river upon the first flood; and as this is a work capable of estimation, I have hereto annexed an Estimate thereof.

Durham, 2d June, 1761.

J. SMEATON.

ESTIMATE for the probable expence of clearing the channel of the river *Wear* 176 yards, being the distance of the situation of the first lock, as proposed by the Gentlemen Coal Viewers, above the situation as staked out in November 1760, by JOHN SMEATON.

	£.	s.	d.
To 176 yards of water-tight wearing, at 4 <i>l.</i> 10 <i>s.</i> per yard, - - - - -	792	0	0
To fixing a temporary cross dam, at the tail of the <i>Wear</i> , and taking the same away, - -	10	0	0
To drainage of the water while the silt is getting out, supposing 30 days, at 6 <i>s.</i> 8 <i>d.</i> per day,	10	0	0
To getting out 1760 cube yards of matter, at 6 <i>d.</i> - - - - -	44	0	0
	<hr/>		
	856	0	0
To unforeseen accidents at 10 per Cent.	85	12	0
	<hr/>		
	941	12	0

N. B. The 176 yards of water-tight dam is intended to be executed with oak, in a durable manner, so as to remain a fence against the silt of the river.

General ESTIMATE for completing the first lock and dam, at or near JACKSON'S,
near *Harraton*, upon the River *Wear*.

To clearing <i>Biddick Ford</i> , and two other shoals between that and Mr. <i>Lambion's</i> engine drain,	£.	s.	d.
	500	0	0
To wearing and dredging 176 yards from the bottom of the caunch below	£.	s.	d.
<i>Jackson's Ford</i> , up to the tail of the lock, as per former estimate, —	941	12	0
To probable expence in the foundation of the lock at <i>Jackson's Ford</i> , superior to that in its first intended situation, - - - - -	258	8	0
	<hr/>		
			1200
To expence of building the lock in its first situation, - - - - -	900	0	0
To ditto of the dam adjoining, - - - - -	600	0	0
To cutting the ground drain of the water and temporary dam to both, at least, - - - - -	500	0	0
	<hr/>		
			2000
Expence of the navigation from <i>Briddick Ford</i> to new bridge,			3700

N. B. 1st. The expence of the machines, shops, utensils, &c. together with the necessary materials for beginning the work, will be at least 1000*l.* and if the work goes on no further than the first lock, there will be at least 500*l.* lost by the articles just mentioned, which otherwise would serve for the whole.

THE RIVER CALDER.

Comparative ESTIMATE for carrying on the navigation of the river *Calder*, by means of a long cut from the figure of 3 lock at F, to above *Dewsbury* low ford at H, and of carrying it partly by the river and partly by 3 short cuts as in the general plan.

ESTIMATE for a mile of cut.

To 14 acres of land at 50 <i>l.</i> per acre, - - - - -	£.	s.	d.
	700	0	0
To cutting, at a medium, 6 feet deep, 16 feet wide at bottom, and 36 at top, at 3 <i>d.</i> per yard cubic, - - - - -	381	7	0
To sodding and batting down the banks, and sowing them with hay-seeds, at 2 <i>s.</i> per rood,	41	16	0
To extra work in forming 8 passing places, at 5 <i>l.</i> each, - - - - -	40	0	0
To 14 quarters of hay-seeds, at 7 <i>s.</i> per quarter, - - - - -	4	18	0
	<hr/>		
Expence of land, cutting, &c. per mile, - - - - -	1168	1	0

ESTIMATE

ESTIMATE for the navigation by the long cut.

	£.	s.	d.
To 2½ miles at 1168 <i>l.</i> 1 <i>s.</i> per mile, land and cutting,	2628	2	0
To extra work in digging two lock-pits, at 30 <i>l.</i> each,	60	0	0
To 3 carriage bridges of wood, at 60 <i>l.</i> each,	180	0	0
To 3 tunnels for draining, at 10 <i>l.</i> each,	30	0	0
To 1 lock building, at 600 <i>l.</i> and 1 ditto at 400 <i>l.</i>	1000	0	0
To 1 low dam at the head of the cut,	300	0	0
To extra work in banking near <i>Millbank Quarry</i> , and cutting through a rising ground near the <i>Warren House</i> ,	150	0	0
	<hr/>		
To contingencies on the above articles at 10 per Cent.	4348	2	0
	434	16	0
	<hr/>		
Total	4782	18	0

ESTIMATE for the navigation as by the general plan.

To ¾ of a mile of cut, at 1168 <i>l.</i> per mile,	1022	0	0
To extra work in digging 3 lock-pits, at 40 <i>l.</i> each,	120	0	0
To 3 tail-bridges for the locks, at 20 <i>l.</i> each,	60	0	0
To 1 tunnel for drainage, at 10 <i>l.</i>	10	0	0
To 2 locks building at 600 <i>l.</i> and 1 at 400 <i>l.</i>	1600	0	0
To 1 dam at 500 <i>l.</i> and 1 ditto, at 300 <i>l.</i>	800	0	0
To extra expences in crossing the <i>Calder</i> , [-	100	0	0
To extra expence in removing the new mill cloughs, and setting piles to prevent the boats going over the dam,	100	0	0
	<hr/>		
To contingencies on the above articles, at 20 per Cent.	3812	0	0
	762	8	0
	<hr/>		
Total	4574	8	0

TETNEY HAVEN NAVIGATION.

The REPORT of JOHN SMEATON, Engineer, concerning the practicability, &c. of a scheme of navigation from *Tetney Haven* to *Louth*, in the county of *Lincoln*, from the view taken thereof in August, 1760, as projected by Mr. JOHN GRUNDY, Engineer.

HAVING carefully examined the scheme of navigation proposed by Mr. JOHN GRUNDY, for making a navigable canal from *Tetney Haven*, to the upper end of *Avingham* out-fen; and from thence to join the river *Lud*, or *Louth* river, between *Ringer's* drain and *Avingham* mill; and from thence, partly by the course of the river, but chiefly by a new canal, up to new bridge, at or near the town of *Louth*; and having carefully compared the said scheme with the lands through which the aforesaid navigation is proposed to pass, and also examined, as well the principal water-courses, eau-moats, and out-falls, as the havens and communications with the sea and river *Humber*, which relate to the above said scheme, I am of opinion as follows:

1st. That *Tetney* haven is the most proper out-fall for a navigable canal, as being both safest and deepest, and affording a communication with the inland navigations of *Yorkshire* and the *Trent*, for flat-bottomed barges, without going to sea, which, at some seasons of the year, would be dangerous or impracticable.

2d. That the course of the intended canal, as laid down in Mr. GRUNDY's plan, from Mr. YOUNG's warehouse, near *Tetney* haven, to its junction with the *Louth* river, between *Ringer's* drain and *Avingham* mill, is the most eligible position, both for the purpose of navigation and drainage, as passing in general through the lowest grounds.

3d. That the rest of the intended navigable course, from the junction of the canal with the river as aforesaid, to *New Bridge*, near the town of *Louth*, as marked out in the said plan, is also very proper, and does not seem likely to be attended with any particular prejudice to the owners of the adjacent grounds, more than what is inseparable from the nature of the undertakings of this kind.

4th. That the owners of the low grounds, that are liable to be affected by the *Tetney* river, will, in particular, receive great benefit from this undertaking; because,

5th. The

5th. The water of *Tetney* river being received into the navigable canal before it meets the sea sluice or lock, as the water of this canal is, by the said proposed scheme, to be kept constantly lower by 1 foot than low water mark of the *Tetney* river, under *Sheep's* bridge; it follows, that the surface of *Tetney* river will, at its out-fall into this canal, be kept at least one foot lower than it could be by placing a sea sluice at or near *Sheep's* bridge upon the present course of the river.

6th. I am of opinion, that the carrying the navigation up the *Tetney* river further than *Sheep's* bridge, will no way contribute to the more effectual drainage of the *Tetney* lands, and will carry the canal considerably out of its due course; but that a navigation for lighters and small vessels may be separately made up the *Tetney* river to *Tetney*, at a small expence.

7th. That the surface of the water of the canal, being kept one foot lower than the point of low water at *Sheep's* bridge, will be lower than the surface of the water in all the drains that it will intersect; and consequently, that the water of those drains being turned into the canal, will afford a means of draining those lands more effectually, or may occasionally be kept up at their present level by small shuttles, or stops, near the side of the canal.

8th. Where the passages for waters from springs, for watering grounds and other purposes, are intersected by the intended canal, and are desired to be continued in their present course, they may be continued by subterraneous passages or tunnels, as has already been observed in Mr. GRUNDY's Report.

9th. That the principal conveyance of spring water next to *Tetney* river, appears to be that of the *North Coates Fleet*, the surface of which lays higher than the surface of the intended canal, and therefore will discharge itself into the same; consequently, if there should be any objection from *Tetney*, against supplying the navigation in dry seasons from their river, such supply may be had from *North Coates Fleet*, or other sources, having communication with the canal upwards.

10th. I am further of opinion, that which ever of these ways are thought most eligible, that the sea lock ought to be provided with ebb-gates, or gates pointed landward, as well as seaward, that the water may be retained in the canal to its due height, and to enable the vessels to pass at all times when there is depth of water without the sea-lock; it also appears to me, that the purpose of the lock will be as effectually answered, by taking in one vessel at a time, as by taking in two.

11th. That

11th. That in case the several parishes concerned could be agreeable, that the redundancy of one parish should contribute to the defects of another, this canal would be the best means of performing it; for a part of the water of *North Coates Fleet*, or *Tetney* river, being admitted into the canal, all those grounds contiguous, or which might be brought to communicate with the canal, quite up to *Avingham* out-fen, might, by proper drains, be supplied with spring water.

12th. That according to the modern practice of building locks, they are capable of being made and preserved water-tight, wherever this circumstance is necessary.

13th. That according to this scheme, no water will be turned away from *Ringer's* drain, and the eau-moats, except what is necessary to fill a part of the first lock upon the canal near the upper end of *Avingham* out-fen.

14th. That on the 7th day of August, 1760, after the driest season that has been known in the memory of man, I carefully examined the discharge of water by the *Louth* river in 24 hours, at *Thorold's* mill, being the first below the new bridge at *Louth*, and compared the same with the discharge at *Avingham* mill, and found the quantity such as to fill the said first lock, near the upper end of *Avingham* out-fen, to the height required for the passage of a barge 200 times in 24 hours. So that, even in the driest seasons, the quantity of water expended by the navigation will be so very inconsiderable, in proportion to what will still remain, that the difference will be quite insensible to the occupiers of lands.

15th. That there is a possibility that even this inconsiderable loss of water may be totally prevented in scarce water times; but at an expence to the undertaking which so inconsiderable a quantity does not seem to merit.

16th. That the course of the river from the place of junction of the canal therewith to the town of *Louth*, being narrow, crooked, and generally shallow, with level meadows on one or both sides, and scarcely any part of it in a navigable state; I apprehend it will be more eligible and less expence to dig a new canal, with locks upon the same, at proper distances, than to pursue the old course of the river; and that the scheme above referred to, is very proper for this purpose.

17th. That the rise of the river, from the place of junction of the canal with the river, as aforesaid, to *Keddington* old mill, is very gentle, being in length about $2\frac{1}{4}$ miles,
and

and rise about 24 feet, according to Mr. GRUNDY's survey; from thence to a meadow a little below the leather mill the ascent is more sudden, being $11\frac{1}{2}$ feet in three quarters of a mile; and from thence to the new bridge at *Louth* still more, being about 21 feet in the same space.

18th. I am therefore of opinion, that the distance of three quarters of a mile from the leather mill, to the new bridge at *Louth*, will be, in proportion to the distance, the most expensive part of the undertaking; but that a considerable sum will be saved by terminating the navigation at *Kiddington* old mill, to which place it may be brought on very moderate terms.

Austhorpe, July 14, 1761.

J. SMEATON.

GENERAL ESTIMATE of the expence of making a navigation from *Tetney Haven* to *Louth*, according to Mr. GRUNDY's plan.

	For barges with canals wide enough for two to pass in all places.	For barges with canals for one, with passing places.	For lighters drawing 2 feet water.
	£.	£.	£.
From <i>Tetney Haven</i> to the new bridge at <i>Louth</i> ,	15,590	13,686	10,884
From <i>Tetney Haven</i> to the meadow below the leather mill, - - - - -	12,968	11,241	8,931
From <i>Tetney Haven</i> to <i>Kiddington</i> old mill,	11,098	9,481	7,589
From <i>Tetney Haven</i> to the top of <i>Avingham</i> out-fen, - - - - -	7,853	6,566	5,312

N. B. In the above estimate the expence of procuring an act of parliament is not included. The marsh land is estimated at 10*l.* and the meadow at 20*l.* per acre; the ground covered is reckoned at half value, or, what is the same thing, at half quantity: the quantities to be purchased are as under, so that whatever alteration there may be in the price now supposed, the difference may be applied without affecting the other articles.

	2 barge canal. acres.	1 barge canal acres.	canal for lighters. acres.
Marsh lands, - - - 57 - - -	45 $\frac{1}{2}$	- - -	40
Meadow land, - - - 32 $\frac{1}{2}$ - - -	26	- - -	22 $\frac{1}{2}$
Total acres, 89 $\frac{1}{2}$	71 $\frac{1}{2}$		62 $\frac{1}{2}$

Austhorpe, July 14, 1761.

J. SMEATON.

The

RIVER WITHAM.

The REPORT of Messrs. JOHN GRUNDY, LANGLEY EDWARDS, and JOHN SMEATON, Engineers, concerning the present ruinous state and condition of the river *Witham*, and the navigation thereof, from the city of *Lincoln*, through *Boston*, to it's outfall into the sea ; and of the fen lands on both sides the said river : together with proposals and schemes for restoring, improving, and preserving the said river and navigation, and also for effecting the drainage of the said fen lands : to which is annexed a plan, and proper estimates of the expences in performing the several works recommended for those purposes.

INTRODUCTION.

THE river *Witham*, from *Lincoln* to *Boston*, falls in a crooked course through the low grounds of the several lordships following, on the south side thereof, viz. *Lincoln*, *Canwick*, *Washinborough*, *Branston*, *Potter-Hanworth*, *Noston*, *Dunston*, *Metberingham*, *Blankney*, *Marion*, *Timberland*, *Timberland-Thorpe*, *Walcot*, *Billinghay*, *Billinghay-Deles*, and *Dogdike*, to *Chappel Hill* ; and on the north side through the low grounds of *Monks*, *Greetwell*, *Willingham*, *Fiskerton*, *Barlings*, *Stainfield*, *Bardney*, *Southbrey*, *Tupholm*, *Bucknall*, *Horfington*, *Stixwold*, *Swinefike*, *Woodball*, *Thornton*, *Kirkstead*, *Tattersball*, and *Coningsby* : and from the said *Chappel Hill* it runs, in a very crooked and meandring course, betwixt the large and extensive fens called *Holland Fen* on the south, and *Wildmore* and *West Fens* on the north, to *Room's Hall*, and from thence, through some inclosures, to *Boston*, and from *Boston*, through the *Higb Marishes*, into the great bay called *Metaris Estuarium*. The distance from *Lincoln* to *Boston*, by the old course of this river, is about 43 miles.

This river has formerly been a very good navigation from it's outfall at the *Scalp* to *Boston*, (which is about 4 miles) sufficiently capacious and deep to navigate large ships into the town, and from thence to convey barges, keels, and other vessels, to *Lincoln*, almost at all times in the year ; and a very extensive and advantageous branch of commerce has, till of late years, been carried on by the said river, to the great benefit and advantage, not only of the city of *Lincoln* and town of *Boston*, but also of the several towns and villages adjoining upon, and contiguous to it, through an extent of country for many miles in length and breadth.

It was also, when in the aforesaid state and condition, the mother river and outfall for the drainage, not only of the low grounds and fens aforesaid, but also of the low grounds of *North Kyme Fen*, *South Kyme Fen*, *Hart's Grounds*, *Great and Little Bets*, *Rakes*, *Heckington Fen*, *Lady Frazer's 600 acres*, *Ewerby*, *Howel*, *Afgarby*, *Great and Little Hales*, *Brothertoft*, *Anwick*, *Ruskington*, *Dorrington*, *Digby*, *Marcham*, *Hundel-House*, *Revesby*, *Middleham*, *Moor-House*, *Meer Booth*, *Hermitage*, *Newbolme*, *West-House*, *Lang-rike*, *Fritb Bank*, *Langworth*, *Swinecote*, *Stickford*, and *Stickney*; and also of many other low grounds and fens lying more distant and remote therefrom, (but having their outfalls for drainage into it) containing in the whole, by estimation, upwards of 100,000 acres.

This once so flourishing river and country have, for many years last past, been falling into decay, by the banks of the said river being suffered to become ruinous, and incapable of sustaining and confining the water in times of high country floods, so that those flood waters, which were necessary and used heretofore, by their velocity and weight, to cleanse out the sand and sediment brought up by the tides, have been, and now are, suffered to run out of their ancient and natural course, and expand over the adjoining fens and low grounds, whereby those sands, for want of a reflowing power of adequate force to carry them back, have now so much choaked up the haven from *Boston* to the sea, that for several years last past the navigation thereof has been lost for shipping, and it is now become even difficult for barges of about 30 tons burthen to get up to the town in neap tides. And for several miles above the town of *Boston* the said river is totally lost; insomuch that it's bottom is, in many parts, some feet higher than the adjoining low grounds, and the scite thereof converted into grazing and farming purposes.

This mischievous effect has not only been destructive to the navigation of that river, but also to the drainage of the aforesaid vast tracts of fens and low grounds, by reason that many of the mouths of the inward drains, dikes, and sewers, which should have their outfalls into this river, are totally landed up, and lost, and have not run at all for many years into it; and the few that have their outfalls so low as *Boston*, and below it, are nevertheless, in all dry seasons, so much choaked up and obstructed, that the said fens and low grounds must be, in some parts, considerably under water, before they can have vent through their outfalls into the said river or haven, whereby the flood-waters lye so long stagnant thereupon, as to destroy the herbage thereof, and render them not only useless and unprofitable, but also extremely noxious and unwholesome to the adjacent inhabitants.

To find out proper and necessary expedients to improve this river and fens, surveys and levels were taken, some years ago, from *Wiberton Roads* to *Lincoln*, not only along the course of the said river, but also on the adjoining fens and low grounds, to compare their different surfaces, both with respect to the said river and their outfalls to sea; in consequence of which a scheme was formed, and published in the year 1744, by Messrs. GRUNDYs, Engineers, recommending such expedients as, to them at that time, appeared proper for effecting the above desirable purposes; upon which, several meetings have from time to time been held, to consider this and other schemes, and many clauses were prepared for a bill, particularly at a meeting held at *Lincoln*, in November, 1753, and others subsequent thereto.

In the year 1760 Mr. LANGLEY EDWARDS was employed to make views of the premises in question, and since then Mr. GRUNDY, the son, has resurveyed the river and fens, and both have made their several reports thereupon; which said surveys, levels, resolutions, and reports being duly considered, and a fresh view taken of the river and fens in October, 1761, by Messrs. GRUNDY and EDWARDS, in conjunction with Mr. JOHN SMEATON, Engineer, we, the said JOHN GRUNDY, LANGLEY EDWARDS, and JOHN SMEATON, are jointly of opinion as follows, viz.

R E P O R T.

IN the first place it appears to us, that from the great tendency of this river to silt, and the great advance the same has made in the space of 20 years, that in all human probability within the compass of a few years more, not only the outfalls of the present effective drains near *Boston* will be totally lost, but the whole river landed up, unless sufficient measures are speedily taken to prevent it; and the most eligible means for so doing, we conceive, will be to make and preserve a mother river, of sufficient depth and capacity, to effect a general drainage of the several fens and low grounds aforesaid, and also to restore this lost navigation, from the sea through *Boston* to *Lincoln*, and into the *Brayford Meer*, (which has a navigable communication through the *Fossdike* with the river *Trent*) upon the following principles, and by the following methods, viz.

1st. That the new proposed river be made in the shortest direction that can be, consistent with the lowest surface of the country, considered in a medium proportion, and most convenient for receiving the waters thereof.

2d. That its dimensions be such as to be capable of receiving and discharging, not only all the upland waters, but also all those of the several branch rivers and drains that fall into it.

3d. That its banks be made of sufficient strength and height to confine the flood waters within them, and to force them down to sea, without overflowing the adjoining fens and low grounds.

4th. That its bottom be made with a regular declivity from *Lincoln* to the sea ; which, according to the levels, will be at a medium near $5\frac{1}{2}$ inches per mile.

5th. To collect all the living waters into this new river that can be obtained, by scouring out and imbanking all side rivers, rivulets, and brooks that bring down such living waters out of the high country into it, in order to obtain a reflowing force that shall be capable of driving out such matter as is left by the tides, by which means only the outfall below can be preserved open and clean.

6th. To stop the tides from flowing at all into this new river, that its depth and dimensions may be preserved.

7th. That this work shall be so constructed, that navigation may be carried thereon so, as in no wise to interfere with, or prejudice the drainage.

8th. That the necessary works be constructed to retain the fresh water, to be made use of as occasion shall require, for the well watering the said fens and low grounds in dry seasons for the use of cattle, &c.

And lastly. That no salt water be admitted into the mother river, or drains, above *Boston*, by means of the proposed navigation.

The SCHEME for the Drainage.

1st TO erect a sea sluice, for stemming the tides between *Lodowicks Gowt* and *Boston Bridge*; and we recommend a piece of ground, commonly called *Harrison's* four acres, at (A) (see the plan for that purpose), the floor whereof to lie level with low water mark at *Wibberton Roads*, and its neat capacity or clear waterway to be 50 feet, with three pair of pointing doors to the seaward, to shut with the flow of the tides, and drop or draw-doors on the land side, to be shut occasionally, to retain fresh waters in dry seasons; the top of these draw-doors to be gaged to such a height, as to retain the water of the river, not higher, at ordinary seasons, than 2 feet below the surface of the lowest lands that drain therein.

2d. To make a new cut from this sluice to, or near, *Anthony's Gowt*, (A B) in as straight a direction as the nature of the ground will admit of; 80 feet broad at the top, 50 feet broad at the bottom, and 10 feet deep: and from the said place at, or near *Anthony's Gowt*, to make a new cut (in as strait a direction, also, as the nature of the ground will admit of) through *Wildmore Fen* to *Chapel Hill* (C), at a medium, 66 feet wide at top, 50 feet wide at bottom, and 8 feet deep. The earth coming out of this new river to be disposed of in forming banks, which are proposed to be set 40 feet distance from the Brink of the river.

3d. The river, from the upper end of this new cut, at *Chapel Hill*, to *Lincoln*, is proposed to be continued in its present course; but the shallow parts thereof to be scoured out and deepened, where necessary, so as to be every where of the following dimensions at a medium, viz.

For three miles and a half above *Chapel Hill*, 60 feet broad at the top, 40 feet broad at the bottom, and $5\frac{1}{2}$ feet deep below the present bottom. From thence to *Washingborough* lordship, above *Bransford Dyke*, (being about $12\frac{1}{2}$ miles) this river (having the waters of several rivulets and brooks to receive within those limits) should be 40 feet wide at the top, 30 feet wide at the bottom, and 2 feet deeper than its present bottom, at a medium. From hence to *Stamp End*, in *Lincoln*, (being about 10 miles) to deepen the shoals in the old river, so as to be 30 feet broad at the top, 24 feet broad at the bottom, and $2\frac{1}{2}$ feet deeper than they now are on an average.

4th. To make and erect one waggon bridge at (D), and two horse bridges, (E and F), with necessary gates and fences for continuing the roadway and other communications, and for dividing the *Wildmore* and *West Fens* from *Holland Fen*.

5th. To scour out and imbank *Kyme Eau*, from *Dampford* sluice to the river, or so much further as may be found necessary, so that its banks may be 30 feet feat, 6 feet at the top, and 6 feet high.

6th. To scour out *Tattershall Bane*, from the mouth thereof to *Dickinson's* engine, and repair the banks thereof, so as to be 30 feet feat, 6 feet at the top, and 6 feet high.

7th. To scour out and imbank *Billingbay Skirth*, from the *Witham* to *Billingbay Town*, so that its banks may be of the same dimensions as the former; and also to scour out and imbank the *Skirth*, from *Billingbay Town* to *Kyme* causeway bridges, so as to be of proportionable dimensions, for draining the low grounds above the said causeway.

8th. To scour out *Barling's Eau*, from the river to *Barling's Abby*, and repair the banks thereof, so as to be 15 feet feat, 5 feet at the top, and 5 feet high; and also to dike out and embank *Stainfield Beck* proportionable to the former.

9th. To scour out and imbank *Dun's Dike*, from the river *Witham* to the *Carr Dike*, (or instead thereof to reinstate the *Car Dike*, and turn its waters therein,) so that its banks may be 15 feet feat, 5 feet at the top, and 5 feet high.

10th. To scour out and imbank *Nofton Dike* and *Hare's Head Drain*, from the river to the *Carr Dike*, so that its banks may be 12 feet feat, 4 feet at the top, and 4 feet high.

11th. To scour out and imbank *Washingborough Beck*, from the river to the *Carr Dike*, of the same dimensions as the last.

12th. To scour out *Tupham Dike*, *Bardney* or *Tilehouse Beck*, *Southery Eau*, and *Stixwold Beck*, and imbank the same proportionate to the flood waters they bring down.

N. B. *Lodowick's Gowt* will be wanted for discharging the river waters during the execution of the work.

And, for the more certain drainage of *Wildmore* and *West Fens*, a new cut and sluice, to supply the place of *Anthony's Gowt*, be made and erected by the side of the said new proposed

proposed river, and that the floor thereof be laid as low as the bottom of the said river.

When the works above recommended are put in practice, and have had the necessary time to produce their effects upon the out-fall, we are of opinion, that the surface of the water in the New River will be capable of running at least 4 feet lower at ordinary seasons, than at present it can do, and consequently that not only all the lands lying immediately thereupon will be put into a condition of effectual drainage, but also such parishes which at present drain by engines into *Holland Fen*, or into the several sewers bordering thereupon, and will likewise be of service in affording a more ready discharge of the downfall waters from the lands lying still further from their out-fall.

The SCHEME for Navigation, viz.

1st. TO erect a lock with two pair of doors, pointing to the landward, for the purposes of navigation, and one pair of doors pointing to seaward, to keep out the tides.

2d. Upon mature consideration, and comparing the advantages and utility with the increase of expence, we are of opinion, that locks are greatly preferable to staunches, though the expence of the former will be considerably more than the latter. We therefore propose to erect three locks in proper places, by the side of the mother river, betwixt the sea sluice and the city of *Lincoln*, to retain the waters therein for the purposes of navigation in dry seasons (which at the same time will be subservient to the watering of cattle) and one above *Sincil dike* in *Lincoln*, to communicate the navigation of the *Witham* with the *Fossdike*; but that the said locks may not be prejudicial to drainage in wet seasons, the three former are to be so limited in their height, that they shall not retain the waters of the main river any higher than within two feet of the natural surface of the lowest grounds above them; and the weirs or wastes appertaining thereto, shall be composed of flood gates, which together shall be of the same capacity with the river, in the respective parts where such locks are to be erected, and the latter (proposed to be erected above *Sincil dike*) shall be limited to such height, as not to pen the waters higher than the present natural staunch at *Brayford Head*, and that a waste or weir be erected at the upper mouth of *Sincil dike* at G, at the same level with this lock, so that no prejudice may

be occasioned thereby to the present state of the *Fossdike* navigation, or to the low grounds above *Lincoln*.

3d. For the careful and safe management of the locks, and that the waste gates may be at all times opened upon the approach of any flood, or when the river is overcharged with water, a dwelling house is proposed to be built against each lock, and a watchman to be fixed in each to take care thereof.

4th. To deepen the bed of the river, betwixt staunch and staunch, sufficient for the purpose of navigation, which at a medium will be about 13 inches, which done will make 3 feet navigation.

5th. To make proper halingsways for men and horses on the banks and forelands of the said river, and that no damage may be done thereby, proper gates, bridges, styles and fences be put down betwixt property and property, through which the said halingsways may lead.

An ESTIMATE of the expences that will probably attend the execution of the foregoing proposed works, viz.

The SCHEME for drainage.

	£.	d.
The sea sluice near <i>Boston</i> to be laid level with the low water mark at <i>Wibberton</i> roads (which is 3 feet 1 inch and 9 parts lower than <i>Lodowick's Gowt</i>) with a timber floor, supported by dovetail and bearing piles, braces and tyes, with a superstructure of brick and stone, with three arches to contain 50 feet neat waterway, the sea and land doors of oak, &c. &c.	4000	0 0
To making the new cut from this sluice, to or near <i>Anthony's Gowt</i> (being 760 roods at 20 feet to the rood) so as to be 80 feet broad at the top, 50 feet broad at the bottom, and 10 feet deep at a medium, will contain 32½ floors in a rood, and for the whole length 24,700 floors, which, as the earth is to be barrowed to the distance of 40 feet from the brink of the river on each side, and laid in bank fashion, and on account of the great depth of the said cut, will cost about 5s. per floor (or 400 cubical feet) and comes to	6175	0 0
The inclosed land to be cut through will contain about 6 acres, which, at 30 <i>l.</i> per acre, comes to	180	0 0
The forelands and cover of the banks will contain about 13½ acres, which, at 15 <i>l.</i> per acre, is	202	10 0
The commons to be cut through will contain 22 acres, which, at 10 <i>l.</i> per acre, is	220	0 0
The forelands and cover will be 49½ acres, which, at 5 <i>l.</i> per acre, is	246	5 0
F	Carried over	11023 15 0

	£.	s.	d.
Brought over	11023	15	0
To taking away the old banks, and cutting across the old river	200	0	0
To erecting a new sluice at <i>Anthony's Groat</i> , and making the communication cut	600	0	0
To making a new cut across <i>Wildmore Fen</i> , from or near <i>Anthony's Groat</i> , to <i>Chappel Hill</i> (being 1848 roods) 66 feet broad at the top, 50 feet broad at the bottom, and 8 feet deep on an average, will contain 232 floors in a rood, and for the whole length 42873,6 floors, which, at 4s. per floor, comes to	8574	14	5
The land to be cut through will contain 56 acres of common fen land, which, at 10l. per acre, comes to	560	0	0
The forelands and cover of the banks will contain 136 acres, which, at 5l. per acre, comes to	680	0	0
To scouring out three miles and a half above <i>Chappel Hill</i> , so as to be 60 feet broad at the top, 40 feet broad at the bottom, and 5½ feet deep below the present bed, will contain 13½ floors in a rood, and for the whole length (which is 924 roods) 12705 floors, which, at 4s. per floor, comes to	2541	0	0
To diking out the old river where necessary, and imbanking the same from thence to <i>Lincoln</i> , being in length 22½ miles, which, being estimated at 150l. per mile at a medium, comes to	3375	0	0
To erecting a waggon bridge over the new river, in the road from <i>Langrike Ferry</i> to <i>Horn-castle</i> , and two other bridges for communication of the cattle for the use of the commons, and to making good the fencing betwixt <i>Wildmore</i> and <i>West Fens</i> and <i>Holland Fen</i> , about	1000	0	0
To repairing <i>Lodowick's Groat</i> , and making proper cuts to discharge the water during the work, leaking out water in the reaches, &c.	1400	0	0
To materials of barrows and planks, tressells, gang ladders, engines, and other utensils, &c. and carriage of them to the work	1200	0	0
To scour out and imbank <i>Kyme Eau</i> , from <i>Dampford Sluice</i> to the river, and repairing the banks thereof according to the scheme	1000	0	0
To ditto of <i>Tatterball Bane</i> , of the same dimensions as the last, from the <i>Witbam</i> to <i>Dickinson's Mill</i>	300	0	0
To ditto of <i>Billinghay Skirtles</i> , from the <i>Witbam</i> to <i>Billinghay Town</i> , and from thence to <i>Kyme Causeway Bridges</i> , as per scheme	800	0	0
To ditto at <i>Barling's Eau</i> and <i>Stainfield Beck</i> , and repairing the banks thereof to the dimensions mentioned in the scheme	500	0	0
To scouring out and imbanking <i>Duns Dike</i> (or the <i>Carr Dike</i>) as directed in the scheme	400	0	0
To ditto of <i>Nacton Dike</i>	275	0	0
To ditto of <i>Walsingham Beck</i>	60	0	0
To ditto of <i>Tupham Dike</i> , <i>Mardney or Fishbowl Beck</i> , <i>Saunders Eau</i> , and <i>Stirwold Beck</i>	360	0	0
To unforeseen and incidental contingencies, superintending, and officers to attend this work	3000	0	0
Total for the works of general drainage	37849	9	5

An ESTIMATE of such works as concern navigation only, viz.

	£.	s.	d.
To making and erecting the side lock or penn sluice, as proposed in the scheme -	1200	0	0
To building 3 locks with proper wastes and flood gates, as per scheme, between <i>Chappel Hill</i> and <i>Lincoln</i> - - - - -	2000	0	0
To three watch-houses, and purchasing the ground - - - - -	150	0	0
To erecting the proposed lock in <i>Lincoln</i> above <i>Sincil Dike</i> , as per scheme - - -	400	0	0
There will also be a necessity to deepen the bed of the mother river for the purposes of navigation, over and above what is required for draining, upon an average 13 inches, from <i>Chappel Hill</i> to <i>Lincoln</i> , which is 26½ miles, and will cost about 80l. per mile, and comes to	2120	0	0
And for deepening the passage from the lock above <i>Sincil Dike</i> , through the high bridge, into <i>Brayford Meer</i> - - - - -	200	0	0
To materials of barrows and planks, engines, gang ladders, tressells, &c. for this work -	500	0	0
To unforeseen contingencies and supervising the works - - - - -	800	0	0
Total for navigation - - - - -	7370	0	0

JOHN GRUNDY.
LANGLEY EDWARDS.
J. SMEATON.

Slcaford, November 23, 1761.

RIVER CHELMER NAVIGATION.

The REPORT of JOHN SMEATON, Engineer, concerning the practicability of making the river *Chelmer* navigable from *Malden* to *Chelmsford*, in the county of *Essex*, from a view thereof taken the 28th and 29th of May, 1762; from whence it appears as follows:

1st. **T**HAT the river above *Chelmsford* bridge, which runs alongside the town for about a furlong, is sufficiently deep and capacious for navigation, and so continues below the said bridge, till within about half a furlong of *Moufeholm Mill*, where it seems too shallow. This tract of the river appears convenient for wharfs and landing-places; but in case it should be thought proper to carry the navigation above bridge, one of the arches must be taken down and rebuilt, none of them being of sufficient capacity for the craft to pass. There is also ample convenience for making wharfs, either by pursuing the *Chelmer*, or by cuts through the level meadows on the north-east side of the town.

2d. *Moufeholm Mill* may be passed by a cut and a lock on either side, but I apprehend with most convenience on the north side, the cut to fall into the river about half a furlong below the mill, where the river makes a remarkable elbow to the north. This will avoid the shoals below the mill; the water from the waste gates of the *Chelmer* near the town to fall into this new cut below the lock, and be conveyed thereby to the point already remarked.

3d. From the point above remarked, the river continues good till about half a furlong above *Harrington's Mill*, where there are further obstructions, which continue below that mill very near to *Sanford Mill*, and below *Sanford Mill* the river is remarkably narrow, winding, and obstructed with weeds and beds of sand and gravel for above a mile, and grows very little better till opposite Captain *Honeden's* house; after that it is still winding, and much obstructed with weeds, &c. till a quarter of a mile above *Boreham Mill*; but below the paper mill the river is again shallow, narrow, and obstructed, so as to be in no respect fit for navigation, till a little below *Langford Church* (which stands within 15 yards of the river); from hence the river is spacious and good down to *How Mill*. The river at *How Mill*, and from half a furlong above, verges so close to the high land, that no cut is practicable there on the south side of the river; but on the north side there is an extent of flat meadows.

4th. Now

4th. Now considering the great difficulties and obstructions that occur in the river, between *Harrington's Mill* and *Langford Church*, a space near upon 7 miles, and that no part worthy of consideration appears at present in a navigable state, except the space aforesaid, about three quarters of a mile between *Boreham Bridges* and *Paper-mill*; and considering that the extra charges in getting into and out of the river, in order to occupy this space, would nearly be equivalent to the expence of continuing a cut by the same, I am therefore of opinion, that the most cheap, as well as effectual method of making a navigation, would be to desert the river at an elbow about half a furlong above *Harrington's Mill*, veering away towards the south-east till it meets the high ground, and then pursuing the skirts of the rising ground, that is, as much as possible the confines between the upland and the meadows, which is in general land of the least value. A cut may be continued with very little interruption on the south side of the river from the point aforesaid, just above *Harrington's Mill*, to another point a little below *Langford Church*, making locks at proper places, so as to suit the declivity of the ground.

5th. The course of the river below *How Mill* becomes again narrow, shallow, winding, and obstructed with weeds for a space of 2 miles, and is not sufficient for navigation till about half a mile above *Bealy Mill*, and from thence it holds good to *Bealy Mill*.

6th. The spring tides flow about 5 feet at the tail of *Baily Mill*, so that lighters come up thither at those tides to take away their goods. At common neap tides there is little or no flux here. The distance from thence to *Malden*, by the course of the river, is somewhat less than a mile; and the water runs upon a gentle declivity at low water, from those mills to *Malden Bridge*. The common spring tides flow 8 feet, or upwards, at *Malden Bridge*, and the neap tides about 3 feet; but the neap tides sometimes fall so short, even here, as not to rise above 1 foot. These observations, concerning the tides, were taken partly from my own observations of the tide marks, and partly from the best information I could procure upon the place.

7th. Considering the natural course of the river from *How Mill* to *Malden Bridge*, as aforesaid, I am of opinion, that the cheapest way to make the most perfect navigation the circumstance will admit of, is to take a cut out of *How Millpond*, with a lock thereupon, leaving *How Mill* to the south, and either keeping wholly to the north of the river, or otherwise intersecting the river twice within three quarters of a mile below *How Mill*, to pass by *Bealy Mill*, without coming into its pond at all, leaving that mill on the south,

South, and keeping down the meadows to drop into the river a little above *Malden Bridge*, on the north side of the river.

'Tis true that the cut might ultimately drop into the river just below *Bealy Mill*, which would save about three quarters of a mile of cut; but as there is, according to the above information, at a medium, near 3 feet more tide at *Malden Bridge* than at *Bealy Mill*, the difference would be, that in one case a communication between *Chelmsford* and *Malden* would seldom be interrupted, and in the other case never open but at spring tides.

Upon the whole, I am of opinion, that though there is a possibility to make the river *Chelmer* navigable by its natural course, yet there is so small a proportion thereof that is at present adapted to navigation, that it will prove the least expence, and by far the most eligible method, to perform the same chiefly by canals, in the manner above specified, which canals being supplied with sufficient bridges for the public roads, carriage and other bridges for communication between private properties, under-ground tunnels and passages for brooks and water-courses, and back drains for carrying off any soakage that may happen where the water is confined by banks above soil; I say, things being thus provided for, the private properties of land will be no otherwise affected, than by so much diminution as shall be necessary for the works themselves. And having made observations on the quantity of water current in the *Chelmer* at the time of this view, I am of opinion, that one sixth part thereof will be sufficient for passing one vessel per day, and consequently that the mills will not be sensibly affected by loss of water, at the same time they are most of them capable of being improved to near double their present produce. Lastly, having considered the above particulars, and made an estimate of the expence, so far as I can judge without a more particular and accurate survey of the whole, supposing the length not to exceed 13 miles of new canal, the whole fall not exceeding 67 feet; and the value of the land not exceeding 60*l.* per acre, 3 feet navigable water, and the whole performed so as not to require above 1*l.* per Cent. per Ann. of the first expence to keep the same in repair for ever, may be done for 16697*l.*

Austhorpe, 21 June, 1762.

J. SMEATON.

POTTERICK CARR.

The REPORT of JOHN SMEATON, Engineer, concerning the drainage of *Potterick Carr*, near *Doncaster*, in the county of *York*; from a view and levels taken in July, 1762.

POTTERICK CARR is a fenny piece of ground, containing, as appears by an old survey of *Saxton's*, about 2300 acres: in its present state, no brook or spring of any account discharges itself thereupon, so that it is affected only by the down-fall waters which fall immediately thereon, and from the higher grounds which border upon the same. These down-fall waters, however, on account of the natural flatness of its surface, the imperfection of its present drains, and the want of a sufficient out-fall to discharge them, generally overflow the whole, or greatest part thereof, during the winter season; which waters are partly discharged by the drains, and partly evaporated by the sun, so as in dry summers to be tolerably dry, as was the case when the present view thereof was taken.

This carr is bounded on the S. E. by the river *Torne*, which runs considerably above the surface of the carr; but is banked off, so as seldom to overflow the same; the whole drainage of the carr is therefore performed by a separate drain, called *Steeking Dyke*, which falls into the *Torne*, near *Rosington Bridge*, about half a mile below the lowest point of the carr.

On the opposite side of the river *Torne*, extending the whole space that river borders upon *Potterick Carr*, and somewhat higher, is *Holmes Carr*, consisting of some hundred acres, which are also banked off from the *Torne*, so as to be seldom overflowed thereby. The surface of this carr, for the greatest part, lays also below the surface of the contiguous river, yet somewhat higher than *Potterick*. This carr is however subject to the same inconveniencies as *Potterick Carr*; for in this are scarcely any drains at all, so that the down-fall water is obliged to find its way over the surface, by a natural declivity, into the river *Torne*.

Part of the south side of *Potterick Carr* is bounded by *Crookbill* bank and drain, which prevents the spring and down-fall waters from *Loversal* from entering the carr, and which are carried by the said drain into the *Torne*, at a place called *Crookbill Nook*.

On the south side of *Crookbill* bank and drain, and bordering on the river *Torne*, is a large tract of low land, called *Wadworth Carr*, the surface whereof lays considerably higher

higher than *Potterick Carr*; but as the out-fall of its drainage is into the *Torne* at *Crookbill Nook*, and the surface of the *Torne* there being some feet higher than at *Rosington Bridge*, the drainage of *Wadworth Carr* is in much the same condition as that of *Potterick Carr*; and this is said to be the case with a large tract of country bordering upon *Wadworth Carr*, and extending upwards as far as *Tickbills*. I therefore propose to consider the drainage of *Potterick Carr* in a two-fold light: first, as it is, or may be, connected with the drainage and improvement of this large tract of country; and secondly, as to what concerns *Potterick Carr* alone.

On this account, I viewed the whole river *Torne*, from *Rosington Bridge*, to the out-fall of its waters at *Austhorpe sluice*, which is a space that, following the banks thereof, cannot be less than 22 miles; I also pursued the drains leading to *Austhorpe sluice*, quite across, by way of the old *Dunn*, to *Tborn sluice*, and from thence into the present river *Dunn*. I also carried a level from the river *Dunn*, at the crimpfal above *Doncaster*, cross the little moor and the high ground, whereon is the road leading from *Doncaster* to *Loversal*, at *Bally out-gang gate*; thence cross *Potterick Carr*, by way of the old *Eau* (a natural lake therein), down to its lowest point, called *Toad Holes*; thence, by way of *Steeking Dyke*, to *Rosington Bridge*, and down to the beginning of the participants drain, about 5 miles below *Rosington Bridge*, and about 300 yards above *Gatewood Bridge*. I likewise carried a level from the surface of the *Torne*, at *Crookbill Nook*, to *Rosington Bridge*, comparing the same with the surface of *Potterick*, *Wadworth*, and *Holmes Carrs*; and, lastly, a level from the surface of the water of the old *Eau*, to the top of the lowest grounds of the bridge on *Cantley Common*, near *Doncaster* horse course. From which views and levels I would lay down the following facts and observations.

LEVELS from the *Dunn* at the *Crimpsal* above *Doncaster*, to the *Participants Drain*, near *Gatewood Bridge*.

	F.	I.
1st. Mean surface of the <i>Crimpsal</i> above the water of the <i>Dunn</i> , opposite <i>Newton</i> , 27 July, 1762,	8	0
2d. Mean surface of the grounds lying between the <i>Crimpsal</i> and the <i>Little Moor</i> , above the said point of the <i>Dunn's</i> surface,	17	0
3d. Mean surface of the <i>Little Moor</i> , above the <i>Dunn</i> ,	14	0
4th. The causeway in the road from <i>Doncaster</i> to <i>Loversal</i> , opposite <i>Bally Out-gang gate</i> , above the surface of the <i>Dunn</i> ,	39	7½
5th. The mean surface of <i>Potterick Carr</i> , about 100 yards within the border thereof, near the Out-gang gate, above the said surface of the <i>Dunn</i> ,	5	2½
6th. The lowest part of the Carr's surface, near the <i>Division Dyke</i> , on the west side of the dyke, and on <i>Loversal</i> side of the Carr, is nearly level with the surface at the former station, and therefore above the <i>Dunn</i> ,	5	2½
	7th. The	

7th. The surface of the water in the old <i>Eau</i> , which may be esteemed the sink of the <i>Carr</i> above the <i>Dunn's</i> surface, - - - - -	F.	I.
8th. The surface of the <i>Carr</i> at the <i>Toad Holes</i> , near the old engine, above the surface of the old <i>Eau</i> , - - - - -	4	4
9th. The surface of the river <i>Torne</i> , just below <i>Rosington Bridge</i> , below the old <i>Eau</i> , including a fall at the bridge made by the carriages driving through the water, amounting to $2\frac{1}{2}$ inches, - - - - -	0	10 $\frac{1}{2}$
10th. The surface of the river <i>Torne</i> , at the bottom of the strait cut or river, extending about a furlong below <i>Rosington Bridge</i> , below the surface of the old <i>Eau</i> , - - - - -	1	9
11th. The surface of the river <i>Torne</i> , opposite a birch tree at the side of the meadow on the south side of the river, about 5 furlongs below <i>Rosington Bridge</i> , below the old <i>Eau</i> , - - - - -	4	0
12th. The surface of the river <i>Torne</i> , just above the houses at <i>Oakly Dam</i> , above the old <i>Eau</i> , - - - - -	4	8 $\frac{1}{2}$
13th. The surface of the river <i>Torne</i> at the foot bridge, about 100 yards below the road at <i>Oakly Dam</i> , below the surface of the old <i>Eau</i> - - - - -	6	0
14th. The surface of the river <i>Torne</i> , at the entry of the <i>Participants Drain</i> , about 5 miles below <i>Rosington Bridge</i> , and about 300 yards above <i>Gatewood Bridge</i> , below the surface of the water in the old <i>Eau</i> , - - - - -	9	6 $\frac{1}{2}$

Consequently,

15th. The surface of the river <i>Torne</i> , at the birch tree below <i>Rosington Bridge</i> , is higher than the surface of the <i>Dunn</i> , at the <i>Crimpsal</i> , by - - - - -	0	4
16th. And the surface of the <i>Torne</i> , at the entry of the <i>Participants Drain</i> , is lower than the surface of the <i>Dunn</i> at the <i>Crimpsal</i> , by - - - - -	5	2 $\frac{1}{2}$

LEVELS from *Crookbill Nook* to *Rosington Bridge*.

17th. The general surface of <i>Wadsworth Carr</i> , near <i>Crookbill Nook</i> , above the surface of the <i>Torne</i> , at <i>Crookbill Nook</i> , as was taken 29th July, 1762, - - - - -	0	9
18th. The mean surface of one of the lowest flades near <i>Crookbill Nook</i> , above the surface of the <i>Torne</i> there, - - - - -	0	1 $\frac{1}{2}$
19th. The mean surface of the lowest part of <i>Holme's Carr</i> , opposite <i>Crookbill Nook</i> , below the surface of the <i>Torne</i> there, - - - - -	0	9 $\frac{1}{2}$
20th. The general surface of <i>Potterick Carr</i> , in the meadows adjoining to <i>Crookbill Nook</i> , below the surface of the <i>Torne</i> there, - - - - -	1	2 $\frac{1}{2}$
21st. The height of the bank of the <i>Torne</i> , above water, at some of the lowest places on the <i>Holme's Carr</i> side, near <i>Crookbill Nook</i> , and which the <i>Torne</i> is said very rarely to over-top, - - - - -	0	11
22d. Ditto, on the side of <i>Potterick Carr</i> , - - - - -	0	11 $\frac{1}{2}$
23d. Surface of the <i>Torne</i> , at the lowest part of <i>Potterick Carr</i> , called the <i>Toad Holes</i> , below the surface of the <i>Torne</i> , at <i>Crookbill Nook</i> , - - - - -	1	8
24th. Surface of the <i>Torne</i> just below <i>Rosington Bridge</i> , including the fall of $2\frac{1}{2}$ inches there, below the surface of the <i>Torne</i> , at <i>Crookbill Nook</i> , - - - - -	3	5

Consequently,

25th. From the general surface of the lowest part of <i>Holme's Carr</i> , near <i>Crookbill Nook</i> , to the surface of the <i>Torne</i> , at <i>Rosington Bridge</i> , there is a fall of - - - - -	2	7 $\frac{1}{2}$
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LEVEL from the old *Eau* to *Cantley Common*.

26th. July 30th, 1762, found the rise from the surface of the water of the old <i>Eau</i> , to the top of <i>Cantley Common</i> , in the lowest part of the ridge between the division dyke and the inclosures next <i>Doncaster</i> ,	-	-	-	-	-	-	-	-	F.	I.
									15	0½

OBSERVATIONS.

27th. From my view of the country, it appears, that there is a fall of some feet from low water mark in the river *Dunn*, near *Thorne Sluice*, to low water mark in the *Trent*, at *Autborpe Sluice*; and from the above levels, Articles 7th and 14th, it appears, that the surface of the *Thorne*, at the beginning of the *Participants Drain*, is lower than the *Dunn* at the *Crimpsal*, by 5 feet 2½ inches; but as this will scarcely balance the difference at *Doncaster Lock*, it follows, that the *Torne*, from the entry of the *Participants Drain*, would have a fall into the river *Dunn*, at or near *Thorne Sluice*, at least equal to the sum of the falls of the four locks upon the river *Dunn* below *Doncaster*, and therefore has at least an equal one into the drain leading to *Autborpe Sluice*, which may probably amount in the whole to 12 or 14 feet, besides the 5 feet 2½ inches above mentioned.

28th. From my view of the country, it further appears, that there is no passage from *Potterick Carr* to the *Dunn*, without traversing the ridge of hills extending from *Loversal* to *Hatfield*, without going below *Hatfield*; and since the same point can be attained by following the valley of the *Torne*, I therefore look upon the cutting through the high ground, at *Cantley Common*, in order to come at the same point, as quite out of the question; and to traverse the aforesaid ridge of hills, after passing through those high grounds, will be less eligible than traversing the same at the out-gang gate, and finding the shortest way to the *Dunn*.

29th. It is generally looked upon, that a capacity of reducing the surface of the water in the drains 2 feet under the general surface of the lowest lands to be drained thereby, to be effectual for draining purposes, and therefore whatever means are capable of producing this effect, will answer the end as well as if they were capable of making a greater reduction, because the surface of the water being too much reduced, with respect to the surface of fen lands, is found to hurt the fertility thereof.

GENERAL SCHEME.

NOW, with respect to the general drainage of the country, I take it for granted, that what will drain the lowest flades of *Wadworth Carr*, near *Crookbill Nook*, will, by proper leading drains, do for all the lands that lay further up the country; but as there appears to be from the levels, Articles 17th and 20th, a fall of almost 2 feet from *Wadworth Carr* into *Potterick Carr*, which would be sufficient for the drainage of the former, yet, was the down-fall waters of *Wadworth Carr* and country above let down, so as to communicate with the drains of *Potterick Carr*, the former would over-ride, and thereby prevent the drainage of the latter, unless both were carried separately to a point where a sufficient declivity might be obtained, so as to carry off both without affecting each other. This purpose may be obtained by cutting new drains separate from the river *Torne*, so as to deliver their water into the *Torne*, at the birch tree, below *Rofington Bridge*, before mentioned (Art. 11.) and still more effectually was the river scoured out, and a bridge built at *Oakley Dam*, where, from Art. 12 and 13, it appears, that $15\frac{1}{4}$ inches of level might be obtained in little more than 100 yards, the loss of which is a great detriment to the grounds lying on both sides of the river, between the said birch tree and *Oakley Dam*, during which space the river being deeper than in most other places, would reduce its surface a great part of that quantity lower than at present.

To this scheme will probably be objected, that the down-fall water of a large tract of country being brought down into the *Torne* at the birch tree, by more direct passages than heretofore, will be the means of overflowing the meadows below the said point, and also raise the waters in the out-fall drain to a greater height than they would otherwise do. And it must be acknowledged, that something of this would take place, though in so small a degree, as scarcely to be sensible at so great a distance from the out-fall; for it must be allowed, that in wet seasons the same quantity of water must be discharged, the only difference is in the time. It must also be allowed, that the water which comes down the drains to the birch tree, must otherwise have come down the *Torne* to the same point, and therefore the water of the *Torne* will be eased by that quantity. The time therefore can only be affected by that part which comes down to the drains quicker than it would have done by the *Torne*; but then in consequence of this quickness being nearer its out-fall, and coming by a more direct road, it will generally happen that the bulk of the down-fall coming by the drains will be gone off, before the bulk of the land waters that come from other places at a great distance by

the meandring course of the *Torne* are arrived ; and consequently, in such cases, the rapidity of the waters coming down will, upon the whole, be rather abated than increased.

But if this reasoning, however true and explicit, should not prove satisfactory to those who are to get nothing by perceiving the truth thereof, I see no way of steering clear of the objection, but by bringing a new drain from the river *Dunn*, entirely independent of the river *Torne* ; and I do not find any better way of doing this, than by beginning at some proper point upon the river *Dunn*, below *Stainford* lock, and above *Thorne* sluice, from thence traversing the level moors, and leaving *Gatewood* to the north, to approach near the *Torne* at *Gatewood Bridge*, and leaving this bridge, as well as the whole river *Torne*, on the south, to follow the low meadows quite away to *Potterick Carr*, and through the same up *Wadworth Carr*, &c.

In this case, it would be necessary to erect a small sluice at the out-fall of this drain into the *Dunn*. This method would effectually drain, not only all the country above *Rosington Bridge*, but be of great service to the lands through which it passed below, and might be executed at a moderate expence ; for though the distance is considerable, yet there is so great a sufficiency of level, as appears by Art. 27, that a small drain would answer the end. This drain would be somewhat shortened, and the out-fall sluice avoided, in case the proposed scheme for making a navigable communication between the *Dunn* near *Thorne Sluice*, and the *Trent* near *Authorpe Sluice*, should take place ; in which case, the two schemes would be of mutual assistance to each other. Yet as the execution of this scheme of drainage, in either method, however practicable in nature and art, would necessarily pass through and sever many properties, how far it may be practicable respecting mens interests and opinions, I cannot take upon me to say.

SCHEME for POTTERICK CARR.

I come now to consider what may be done towards the drainage of *Potterick Carr*, independent of the rest of the country, by such methods as lay within a narrower compass, and as it were within the districts of the corporation of *Doncaster*, and proprietor of *Loversal*. And here two methods offer themselves ; one by a subterraneous passage from *Potterick Carr* to the river *Dunn*, by way of the *Crimpsal* ; the other by way of *Steeking Dyke*, which appears to be the ancient out-fall drain for *Potterick Carr* into the *Torne*, at or near *Rosington Bridge*.

1st. With

1st. With respect to a passage from *Potterick Carr* to the *Dunn* above *Doncaster*, it appears, Art. 7, that when the levels were taken, there was a fall of 4 feet 4 inches from the surface of the old *Eau* to the surface of the river *Dunn*, the distance being about 2 miles. It appears also, Articles 5, 6, 7, and 8, that the surface of the old *Eau* at that time was about 10 inches below the general surface of the *Carr*; therefore a capacity of running off the surface of the old *Eau* 14 inches lower than at present, would, with proper internal drains, compleat the drainage of this *Carr*, and still there would remain 3 feet 2 inches fall from the water of the old *Eau* to the surface of the *Dunn*; but as the verge of the *Carr*, near *Balby* out-gang gate, is about a mile nearer to the *Dunn*, to which all the water of the *Carr* would be brought, in open drains, with very little loss of level, there would be 3 feet descent for the subterraneous passage, which from this point would not, in the nearest direction, be above a mile, which is so large an allowance of descent, that supposing a clean bottom carried upon a dead level from the surface of the *Dunn*, a drain of 3 feet wide would sufficiently discharge the water.

The disadvantages attending this scheme would be, that whenever the surface of the *Dunn* should, in rainy seasons, be kept higher than 3 feet above its common pitch, which I suppose it sometimes is for weeks together, that then there could be no drainage at all; but, on the contrary, without the help of a subterraneous sluice, the water of the *Dunn* would run into the *Carr*.

This inconvenience would, in great measure, be obviated by carrying the drain so low as to fall into the river *Dunn*, between the water-engine and the bridge at *Doncaster*; for this would gain an addition of 5 or 6 feet of level. And though, in the height of great floods, I suppose there is not a great deal of difference of the *Dunn's* surface above and below the engine-dam, yet I suppose that the water rarely continues there for any length of time together, so as to be 3 feet higher in the engine-tail than the ordinary surface of the *Dunn*, at the *Crimpsal*, opposite *Newton*. So that the drainage being stopped but for a little time together, would be sufficiently performed by intervals: but then, as this will create about three quarters of a mile addition of drain, and thereby add to the tediousness and expence of an otherwise tedious and expensive job, it will still remain a question, how far this method of drainage may be eligible, especially when 'tis considered, that, should a running sand be met with in this passage, it might prove an insurmountable difficulty, and the work be obliged to be deserted, after great expences incurred thereupon.

2d. With respect to a drainage into the *Torne*, if *Steeking Dyke* was carried down on the north side of the river, and dropt into the *Torne*, at the birch tree, below *Rosington Bridge*, this scheme would be undeniably the best of any; for to this place, from the old *Eau*, there is near upon the same fall as into the *Dum*, at the *Crimpsal*, opposite *Newton*, with an opportunity of making a drain of any given capacity that may be required, and as it appears, from Art. 21 and 22, that the waters of the *Torne* don't rise in time of floods above a foot perpendicular, the flood water of the *Torne* can never over-ride those of the drain: and whatever force may be supposed to remain in the objection to the delivering the down-fall water of the whole country into the *Torne* at this point, it will entirely vanish when applied to *Potterick Carr* alone; for being of so much less extent, and nearer to its out-fall, and having so good a declivity, its water will be certainly discharged before those from the different parts of the country are come down; and in long-continued rains it is plain that when the *Carr* is once overflowed to a certain height (as is the case at the close of winter, when surface waters are most annoying) that the present discharge of water from the *Carr*, at those times, will be just equivalent to its discharge of water in the same time when in a state of drainage.

But I will now suppose the worst, and take it for granted that nothing can be done but by such lawful means as may be put in practice within the grounds of *Doncaster* and *Loversal*.

It appears by the levels, Art. 9 and 10, that from the surface of the old *Eau* to the lower side of *Rosington Bridge* is a fall of $10\frac{1}{2}$ inches, and from thence to the lowest part of the straight cut, extending about a furlong below the bridge, is $10\frac{1}{2}$ inches more, in the whole 1 foot 9 inches; but as a reduction of the surface of the old *Eau* of 14 inches below its then state has been shewn sufficient for drainage, there will still remain 7 inches fall from the old *Eau* to the point last mentioned, which is amply sufficient, as the distance does not exceed a mile and half.

Now the straight cut aforesaid, below *Rosington Bridge*, (which passes through the bounds of the corporation of *Doncaster*, or Mr. DIXON, of *Loversal*,) plainly appears to have been made with a view to the drainage of *Potterick Carr*: for by cutting off the loops of the old river, and making a more free passage for the *Torne*, the surface of the water would naturally be reduced at the tail of *Steeking Dyke*, and consequently afford a better fall from the *Carr*; and even by this construction, had the whole been done in a proper method, and with proper dimensions, a drainage might have been accomplished, and with good management preserved to this day: but at present I would rather advise to let the

the *Torne* continue its present course, and to cut a new drain on the north side thereof, through the said lands, from the lowest point of the said straight cut, up to *Steeking Dyke*; and either by scouring out and enlarging *Steeking Dyke*, or by cutting a new drain in lieu thereof, this, with proper internal drains within the *Carr*, will reduce the water 2 feet 7 inches within the general surface of the lowest lands in dry seasons, unless held up to a greater height for the use of cattle.

It appears from Art. 21 and 22, that the greatest rise of the *Torne* in time of floods at *Crookbill Nook* does not exceed 1 foot perpendicular; but there is reason to suppose it may be somewhat more at the point before mentioned, possibly 15 inches, and therefore it will be necessary to place a sluice or doors at the tail of the drain to shut against the water of the *Torne* at such times, and prevent their reflowing into the *Carr*; yet, if the drains are made of sufficient depth and capacity to run off the waters of the *Carr* to the dead level of 2 feet 7 inches below soil, those drains will be sufficient to hold water, so as to drain by intervals without overflowing the surface of the *Carr*.

It is possible the same objection may still be urged against this scheme as against the former, of going down to the birch tree, viz. that of bringing down the waters more suddenly upon the lands below; but for this, in the present case, there is most evidently not the least foundation; for since it will be necessary to maintain a pair of doors to shut against the *Torne* in time of floods, it is plain the drainage water can make no addition while its doors are shut; and as they must escape when the bulk of the floods in the *Torne* are spent, it must contribute to the carrying off the whole more equally than at present. And since this scheme can be executed within the grounds of the parties concerned, and cannot possibly, even in appearance, prejudice those of any other, I apprehend there can be no doubt of the legality thereof; and as this scheme can be executed at much less expence than any other, for my own part, I think it merits trial.

I hope what has been said will be sufficient to let the proprietors of *Potterick Carr* see clearly the nature of this business, and to determine them in the choice of a method: when that is done, I shall be ready to make what further observations may be necessary, in order to lay down the particular plan and dimensions, and form an estimate thereupon.

With respect to *Holmes Carr*, it will readily occur, from what has been said, that there cannot be the least difficulty; for since there is 2 feet 7 $\frac{1}{2}$ inches fall from the lowest parts opposite *Crookbill Nook* to *Rosington Bridge*, that nothing more is necessary than to put the

	<i>l.</i>	<i>s.</i>	<i>d.</i>
Brought over	124	11	8
From the aforeſaid drain for 5 chains, through Mr. Copley's cloſe, and from thence 24 chains through the <i>Crimpsal</i> , total length 29 chains, may be an open drain, which at 9 feet mean depth, 6 feet bottom, and 4 feet batter per yard perpendicular, turns out 11494 yards, at 3 <i>d.</i>	143	11	
The mean width of the cut at top will be 30 feet, which in 29 chains produces 6386 yards, equal to 1 acre, 1 rood, 11 perches, and each bank will nearly occupy the ſame ſpace, but this is ſuppoſed to be left of half value, ſo that, for the two banks we reckon 1 acre, 1 rood, 11 perches, and in the whole 2 acres, 2 roods, and 22 perches, which if valued at 60 <i>l.</i> per acre, comes to	158	5	0
From <i>Crimpsal</i> , up <i>Spanſyke Cloſes</i> , 26,26 chains, mean depth 12 feet, with 6 feet bottom, and 4 to 3 ſlopes, will turn out 16995½ yards, at 3 <i>d.</i>	211	18	10½
The mean width at top will be 38 feet, which at 26,26 chains long, makes 7315 yards, equal to 1 acre 2 roods 2 perches, which doubled for the cover makes 3 acres and 4 perches, which if valued at 50 <i>l.</i>	155	0	0
A bridge acroſs at the <i>Extrop Road</i> ,	30	0	0
From the top of <i>Spanſyke Cloſes</i> to the entry upon of the little moor, is 18½ chains, the mean depth 16 feet. The digging out a 6 feet bottom, with half a foot batter, in a foot high, will turn out 10664 cube yards, which at 4 <i>d.</i> comes to	177	14	8
To arching 18,5 chains, at 14 <i>l.</i> 10 <i>s.</i>	268	5	0
To ramming, filling, and righting the ground, at ½ <i>d.</i> per cubic yard,	22	4	4
To temporary damages, at 1 <i>d.</i> per yard ſuperficial of the ground opened, 3138, comes to	13	1	6
From the entry of the little moor acroſs the ſame to the baſe of the hill, about one chain within the <i>Green-Lane</i> , is 23 chains, mean depth 17 feet; the digging out a 6 feet bottom at ½ a foot batter, in 1 foot riſe, will turn out 13859 yards, which at 4 <i>d.</i> a yard comes to	230	19	8
To 23 chains of arching, at 14 <i>l.</i> 10 <i>s.</i>	333	5	0
To filling in 13859 yards, at ½ <i>d.</i>	28	17	5½
From the baſe of the hill, one chain upon the ſame being at a medium 20 feet deep, with bottom and ſlopes as before, containing 782 cube yards, at 5 <i>d.</i>	16	5	10
To arching ditto as before,	14	10	0
To filling ditto, 782 cube yards, at ½ <i>d.</i>	1	12	7
To open caſting on the ſide of the hill next the <i>Carr</i> one chain, mean depth 12 feet, with a 6 feet bottom, and ſlopes as before,	15	0	0
To open-caſting, arching, and filling one chain more, mean depth 16 feet,	27	0	0
To open-caſting, arching, and filling one chain, mean depth 20 feet, as on the other ſide of the hill,	33	0	0
Charge of the out-fall drain, excluſive of the hill,	2005		
The length of the under-ground paſſage through the hill, which cannot be conveniently open caſt, is 13 chains, that is 286 yards; but as the quality of the matter is not known at the depth it is to paſs, it is impoſſible to eſtimate the charge of getting through it; if it turns out any kind of matter that will ſtand unsupported till arched a fathom at a time, it may be done for about 4 <i>s.</i> per yard, pitting included; but as it may be attended with ſome extra trouble, if we allow 2 <i>l.</i> 10 <i>s.</i> per yard, then 286 yards at 2 <i>l.</i> 10 <i>s.</i> come to	715		

Carried over £. 2720 2 7

	£.	s.	d.
Brought over	2720	2	7
To extra work in fixing a drawgate at the entry of the subterraneous passage, in order to take off the water, to repair or inspect any thing within, and which will also serve for holding in water for the cattle in dry seasons, - - - -	20	0	0
Estimated expence of the out-fall drains - - - - -	2740	2	7

N. B. The whole length is 119 chains, or $1\frac{1}{2}$ mile wanting one chain.

Mother drains, barrier bank, &c. within the Carrs.

To digging a mother drain from the entry of the subterraneous passage to the old <i>Eau</i> , being in length $1\frac{1}{4}$ mile, to be 21 feet top, 9 feet bottom, and at a medium 6 feet deep, containing 30800 cube yards, at 2d. - - - -	256	13	4
To continuing the said drain from the old <i>Eau</i> to <i>Crookbill Nook</i> , in order to receive the water by foxes, from <i>Holmes Carr</i> under the <i>Torne</i> , and from <i>Wadworth Carr</i> under <i>Catherine Well Water</i> , being in length $1\frac{1}{4}$ mile, to be 19 feet top, 9 feet bottom, and at a medium 5 feet deep, containing 17111 yards, at 2d. - - - -	142	11	2
To the making a fox, about 2 yards wide and 1 yard high, for taking the water from <i>Holmes Carr</i> under the river <i>Torne</i> , - - - - -	60	0	0
To a ditto, about a yard square, from <i>Wadworth Carr</i> , with a shuttle for regulating the water, that it does not come down faster than the mother drains in <i>Potterick Carr</i> will vent it - - - - -	55	0	0
To cutting a back drain behind the bank of the <i>Torne</i> in <i>Potterick Carr</i> , and thereby strengthening the bank against the river, being in length about $1\frac{1}{2}$ mile, to be 3 yards mean width, and a yard deep, cutting and banking at 2d. per yard, - - - -	66	0	0
To ditto behind <i>Crookbill Bank</i> , 1 mile (or so far as may be found necessary) of the same dimensions, - - - - -	44	0	0
To cutting a mother drain within <i>Holmes Carr</i> , parallel with the general course of the river, avoiding the loops, and therewith forming a bank against the same, leaving 20 feet foreland in the nearest places; the length supposed $2\frac{1}{2}$ miles, (more or less as may be necessary) to be 5 yards top, 2 yards bottom, and at a medium $4\frac{1}{2}$ feet deep, containing yards, at 2d. - - - - -	192	10	0
To cutting a mother drain, in like manner, in <i>Wadworth Carr</i> , disposing the earth bank fashion, as before-mentioned. The drain to be $4\frac{1}{2}$ yards top, $1\frac{1}{2}$ bottom, and at a medium to $1\frac{1}{2}$ deep, supposing the length $1\frac{1}{2}$ miles (more or less, as may be necessary) will contain 11880 yards, at 2d. - - - - -	99	0	0
To strengthening <i>Catherine Well Water Bank</i> against <i>Wadworth Carr</i> by a back drain, 3 yards wide and 1 yard deep, supposing the same 1 mile (more or less, as may be required) - - - -	44	0	0
To banking on both sides the drain by the side of the road over <i>Wadworth Carr</i> , which brings down the water of some springs, and also for making catch-water drains to conduct the upland water into the river, supposing the whole to be $2\frac{1}{2}$ miles, (more or less, as may be wanted) 3 yards wide and 1 deep, - - - - -	110	0	0
Estimated charge of the internal works - - - - -	1069	14	6

GENERAL ACCOUNT.

	£.	s.	d.
The out-falls drain,	2740	2	7
The internal works,	1069	14	6
Contingent expences upon the whole, the perforation of the hill excepted,	400	0	0
Total	4209	17	1

N. B. The sum marked thus † was in the original 2732*l.* 6*s.* 0*d.* and the total marked thus * was 4202*l.* 0*s.* 6*d.*

OBSERVATIONS.

1st. In case a red sand rock should be found in the hill, at the level of the drain that will stand of itself, it may be done for 1*l.* 5*s.* a yard, but in case it should be a soft clay, or running sand, it may cost 10*l.* a yard.

2d. In case of such a sand or clay, it will be adviseable to sink for a firmer matter below, in which case, the water may be carried under the hill in manner of an inverted syphon.

3d. If a red sand rock should lay in a right line between the engine and Carr, as the distance is only 65 chains, it might be cut for about 1828*l.*

4th. If such a rock should be found between the top of *Spanfyke Closes*, in a right line to the Carr, the length being 33 chains, the whole expence of the out-fall drain will be done for 1751*l.* But

5th. If this last space should be the same matter as supposed in the estimate for Out-gang gate, the out-fall drain would be done this way for 2659*l.* but the hazard greater.

6th. As much depends upon the quality of the matter, it would be adviseable to bring this affair to a certainty, by sinking or boring.

7th. The charge of carrying the drain from the top of *Spanfyke Closes* across the little moor to the entrance of the hill, will be somewhat cheaper by an open drain than by arching; but as the cut and banks would occupy between 50 and 60 yards broad, would be less eligible to the land owners, and the drain more liable to obstruction, by matter tumbling from such very high banks.

N. B. The bottom for the arching parts is supposed to be dug no more than 6 feet wide, though the drain within the walls is purposed to be of 5 feet, because the foot of the slopes may be cut down perpendicular half a foot on a side, when the masons are ready to put in the walls.

Doncaster, March 23, 1764.

J. SMEATON.

TO MR. SHEPPARD, concerning *Patterick Carr*.

S I R,

IN answer to your request, my report is as follows:

That in the dry season in July 1762, I found the waters of the old *Eau* in *Potterick Carr* nearly 10 inches below the mean surface of the land in the *Carr*, which in the points I tried it was nearly upon a level, which are specified in my report, and to which I refer; that from the surface of the water in the old *Eau*, to the surface of the river *Terne* just below *Rosington Bridge*, I found a fall of $10\frac{1}{2}$ inches, and from thence to the bottom of the straight cut, or river below *Rosington Bridge*, $10\frac{1}{2}$ inches more, making together 1 foot 9 inches below the surface of the old *Eau*, as it and the river then were; but it is to be remarked, that the surface of the water in the river just below *Rosington Bridge* was 13 inches below the first apparent joint of the arch on the south-east angle thereof, whereas when I viewed it on the 20th of May last, it was nearly 6 inches above the same.

I also find from my notes taken in 1762, that from the bottom of the straight river aforesaid, to the birch tree mentioned in my Report, I made 2 stations, amounting together to 2 feet 3 inches fall; the first below being $11\frac{1}{4}$ inches, and the second $15\frac{3}{4}$ inches; but how far the first station of 11 inches extended below the straight cut, I do not now remember, having no remark thereupon, the extent of the corporation's estate on the south side of the river not being at that time distinctly pointed out to me; but I have reason to believe that at least 6 inches of the 11 would fall within the corporation's estate, so that hence I infer, that from the surface of the old *Eau*, to the surface of the river *Terne*, at the bottom of the corporation's estate, as the old *Eau* and river then were, was at least 2 feet 3 inches, and consequently below the mean surface in the

Carr

Carr 3 feet 1 inch, and which I don't doubt but will appear the same, whenever the obstructions, which I apprehend to be since formed in the river below *Rosington Bridge*, are removed, so as to suffer the surface of the water to subside to the same point upon the bridge, as it was even with in 1762; and consequently, that with the fall above mentioned, the *Carr* may be effectually drained, as 2 feet below the surface is generally esteemed by the most experienced engineers a compleat drainage.

For this purpose, I apprehend it will be convenient to cut a new passage for the river *Torne* from some proper place at or above *Crookhill Nook*, and skirting the high ground on *Rosington* side, as much as consistent with a short course to bring the same down to *Rosington Bridge*, and building a new bridge for the new river on the south side of the present bridge, to carry down the new cut through the corporation's estate on the south side of the present river, and to drop the same into the *Torne* at the lowest point of the said estate. This new river being properly embanked, will defend the lower grounds of *Potterick Carr* from the floods of the *Torne*, and by proper drains and tunnels will drain *Holmes Carr*, and the higher grounds to the westward of the same, without interfering with that of *Potterick Carr*.

The dimensions of this new river ought to be at least 20 feet bottom, with proper batters, or slopes, of at least 1 to 1. The bottom at the tail of the new river to be at least 2 feet below the surface of the *Torne* there, as it was in July 1762, that is, 4 feet 6 inches nearly below the said joint in the arch, and to rise upon a plane regularly inclined, so as to be at least 4 feet below the surface of the adjacent carrs, where it joins the old river at or above *Crookhill Nook*.

For the drainage of *Potterick Carr*, I would recommend to cut a new drain between the proposed new river and the old one, beginning at the old river just above the tail of the new one, and joining the straight river as soon as possible, to widen and deepen the same in its present course, so as to pass under the present *Rosington Bridge*; and from thence keeping on the north side of the old river above *Rosington Bridge*, to join *Steeking Dyke*, widening and deepening the same nearly according to its present course, to the place where the engine stood, from thence keeping a straight course, or as nearly so as the convenience of properties will allow, through the middle of the *Carr* to the north end thereof.

This drain I would recommend to be at least 18 feet wide at the bottom, with slopes of at least 1 to 1, and to be at least 5 feet 6 inches below the said joint in the arch, the
bottom

bottom to be carried upon a dead level, and of an equal width as far into the *Carr*, as till it is opposite the old *Eau*, from thence to grow gradually narrower and shallower, so as to be 4 feet deep and 5 feet bottom at the head ; this, with proper cross drains, will reduce the water in the *Carr* to very near the same level as the river at the out-fall of the drain. I would further advise that a sluice with doors, pointing toward the *Torne*, be erected at the tail of the drain, to prevent the water of the *Torne* in great rains from over-riding those of the *Carr*, and thereby reverting into the *Carr*, and also a stop-sluice with draw-doors upon the tail of the proposed new river, by shutting which, at proper times, the proposed drain will run at times, when it otherwise would not ; a sluice-keeper being appointed to take care of the drawing and shutting the same, so as to prevent their running or penning improperly, on account of the lands above and below.

A catch-water drain round the skirt of the *Carr* will be of great use, in conveying the water from the uplands into the new river, without entering the *Carr* ; but as the country is not very extensive which at present throws down water upon the *Carr*, this expedient need not be put in practice till experience shews it to be wanted.

The above reasoning principally depends upon two points, which I would recommend to the commissioners to satisfy themselves upon, viz. whether obstructions in the river below the corporation's estate can or cannot be removed, so as to run off the water to the same depth as I found it in my survey in July 1762 ; and secondly, whether, in that state of the river, there is or is not the quantity of fall specified, or near upon.

I am, S I R,

Your most humble servant,

JOHN SMEATON.

P. S. The joint of the arch being a little inclined, I took my measure from the lowest side next the water.

The REPORT of JOHN SMEATON and JOHN GRUNDY, Engineers, concerning the practicability of improving the *Fossdyke* navigation, and draining the land laying thereupon; from a view and levels taken in August, 1762.

THE *Fossdyke* is an artificial cut or canal, which joins the *Trent* and *Witham* together, by a navigable communication, extending from the *Trent*, near *Torksey*, to *Brayford Meer*, near the city of *Lincoln*, being in length near upon 11 miles. The river *Witham*, which has its origin near *Post Witham*, in *Lincolnshire*, after pursuing a course of about 40 miles, falls into *Brayford Meer*, which being a natural reservoir of several acres in surface, and having an open communication with the *Fossdyke*, as also with two other still more extensive lakes, or natural reservoirs, called *Swan Pool* and *Cuckoo Pool*, their surfaces being common, and nearly at rest, will, consequently, be nearly upon the same level, and rise and fall together.

The end of the *Fossdyke* next the *Trent* is shut by a lock, having gates pointing both ways, which, of consequence, equally prevent the waters of *Fossdyke* from flowing out into the *Trent*, or the waters of the *Trent* from flowing into the *Fossdyke*, according as each surface happens to be lower or higher than the other. The waters of *Brayford Meer*, and consequently of the *Fossdyke*, are prevented from running off below a certain height, by a shoal in the river *Witham*, between *Brayford Meer* and *Lincoln High Bridge*, called *Brayford Head*, or the *Natural Stanch*. There are also three other passages for the water of the *Witham*, before it falls into *Brayford Meer*, which are called *Sincil Dyke*, and the two *Gowt Bridge Drains*; the two latter join the former, and fall into the river *Witham* below the said shoal of *Brayford Head*, a little above *Stamp End*, which is the lowest point of the city of *Lincoln*; from hence the waters of the *Witham* make their way through the fens towards *Boston*; but as the highest part of the bottom of *Sincil Dyke* and *Gowt Bridge Drains* is several inches higher than the top of the shoal of *Brayford Head*, those serve only as flaker drains, to ease off the passage of the water in time of floods; but *Brayford Head* is considered as the gage, weir, stanch, or tumbling bay, by which the water of *Brayford Meer* is kept up to a certain height, and discharged when above the same.

Now there being a great quantity of low grounds, which have their drainage into *Brayford Meer* and into the *Fossdyke*, and their communications, which cannot, in the present state of *Brayford Meer*, be effectually drained, for want of a sufficient fall from
the

the lowest parts of their surface, it is therefore desirable to the proprietors of those lands that *Brayford Head* should be removed, or at least so far lowered, that the water of *Brayford Meer*, and consequently the *Fossdyke* water, being so much sunk below its present gage surface, as to afford a sufficient declivity from the surface of the lands thereinto.

On the other hand, the *Fossdyke* navigation being at present deficient in depth of water, it is equally desirable to the proprietors thereof that *Brayford Head* should be raised.

To reconcile those opposite interests, and give to each party what they desire, without injury to the other, is the point at present before us.

In the first place it is very obvious that, was *Brayford Head* lowered a certain number of inches, and the bottom of the *Fossdyke* lowered as much, that the lands would be bettered, and the *Fossdyke* navigation would be in the same state as now; and if beyond that the bottom of the *Fossdyke* was lowered as many inches more as it is at present deficient, then the navigation would be bettered also, and both sides would get what they want.

In order to examine the merits of this proposition, we sounded the depths of the *Fossdyke*, and examined the qualities of its bottom, measured the width, and took the height of the banks, in a variety of places, between one end and the other, and made what other observations we could, in order to inform ourselves with the circumstances that would be likely to occur in the execution of such a project: in consequence whereof, we found that (some few places excepted) the bottom was either a rotten peat earth, or else a running sand; and from the efforts that have already been made from time to time, in order to clear the bottom, and by the wharfing up the sides with piles, plank, and stone, as well as from the nature of the soil itself, it appears to us to be very difficult and expensive to preserve the present depth of water upon its present width; and though we are of opinion that the deepening thereof in the requisite degree to answer the purposes aforesaid, is in nature possible, yet, as it appears to us that this deepening cannot be effected without moving one of the banks, in order to widen the same, and give a proper foreland thereto, and that in a very considerable degree for the greatest part of the length, it will, in consequence, not only turn out a very expensive project, which, by an estimate we have made thereof, amounts to upwards of 6000*l.* but be the occasion of much loss of time and profit to the proprietors of the navigation while the

the work is executing ; and, as it appears to us, will not be so eligible even to the land-owners themselves as the following scheme of drainage would be ; for it is most manifest, that no grounds which drain into *Brayford Meer*, *Fossdyke*, or any of the pools or communications that lay upon the same level therewith, can receive any greater prejudice by the present height of water in the *Fossdyke* than heretofore, unless it can be proved that *Brayford Head* is now higher than it was, for if it is not, the expence of such deepening must in a great measure fall upon the proprietors of lands, for whose sake principally it is done, it being no matter which concerns the proprietors of land, how deep the bottom of *Fossdyke* is below the gage surface of its water, but only whether this gage surface is higher now than it was ; if not, and the lessors and lessee of the *Fossdyke* are disposed to be contented with its present depth, rather than be at the charge of deepening, the deepening, with all its consequences, will then become the business of the land owners only, except what it shall be reasonable for the *Fossdyke* proprietors to contribute, for the advantage of a greater depth than at present, after all losses and damages that they shall sustain thereby are made good.

Whether *Brayford Head* is higher now than formerly, is not for us positively to determine ; and though it is possible some accession of matter might have come to *Brayford Head* from various causes and accidents, yet as the shoal is not composed of fixt matter, it may notwithstanding have been upon the whole in a state of diminution, rather than increase, since the increase of traffick, by the passing of boats and carriages upon and over it.

Having viewed and taken the levels of various points of the surface of those lands which drain into *Fossdyke*, *Brayford Meer*, or their communications, we find those most subject to be drowned are as follows.

On the south of *Fossdyke* are *Lincoln Holmes*, *Bootham* low grounds, *Skellingthorpe* low grounds, and part of *Saxelby* pasture : on the north of the *Fossdyke* are part of the *Lincoln Common*, *Burton Fen*, *South Carlton Fen*, *North Carlton Fen*, and a small part of *Broxholme*, *Haddow*, and *Saxelby* low grounds, upon the *Till*.

The surface of the grounds abovementioned are at a variety of elevations above the level of *Fossdyke* water ; yet the greatest part thereof were less than 3 feet, and we found no considerable quantity but what was at the time of this view 1 foot and upwards above the *Fossdyke*, (the greatest part being from 1 foot to 1 foot 6 inches) except the *Hassocks* in *Lincoln Holme*, (being in a manner a bog) a small part of the low slide which

extends from the *Fossdyke* to *Bishop Bridge* on *Lincoln Common*, and a small quantity in *Saxelby* pasture opposite to the *Till*, which were but little elevated above the *Fossdyke* surface. But the lowest ground of any consequence, is a slade extending from *Cuckoo Pool* to *Saxelby* pasture, which appears to have been the course of the *Till* before the *Fossdyke* was originally cut; this was from 5 inches to about a foot above the said *Fossdyke* surface. At the time when this view was taken, there was at a medium, as before mentioned, $4\frac{1}{2}$ inches water upon *Brayford Head*; from the best information there is scarcely ever less than 3 inches, and in great winter floods, full 4 feet; so that it may be reasonably conjectured, and we have been so informed, that in the spring of the year, and at all other times until the said flood waters, which have expanded themselves over that large tract of low grounds above *Lincoln*, are exhausted, there can seldom be less than 10 inches water thereon.

The principal opening for the discharge of those waters of the *Witbam*, and from this tract of land under consideration, is through *Lincoln High Bridge*, which in the narrowest part is no more than $15\frac{1}{2}$ feet; besides which are *Sincil Dyke* and the two *Goat Bridge Drains* aforesaid, which though greater in width when taken together, yet from laying considerably higher, and from those drains being very defective, are not capable of discharging more water than the *High Bridge* singly.

From hence it appears, that the low lands before mentioned, when once overflowed, their drains having an open communication with each other, must remain under water during the winter, and a great part of the spring season, and are without the compass of a compleat drainage in their present situation.

Imbanking and engines are a general method of drainage, which may be put in practice where nothing else can; but the certain expence, and uncertain effect thereof at critical times, have made all drainers prefer the use of natural means, where those natural means can be had.

On examining the *Fossdyke*, we find the general bottom to be about 2 feet 8 inches below the level of *Brayford Head*, in some few places less; but as they are only short distances, they will easily be reduced to a proper depth by dredging, so that there is wanting 10 inches of depth in order to compleat the navigation to 3 feet 6 inches; for the addition that will be made by 3 or 4 inches of water constantly going over *Brayford Head*, will give a sufficiency of free water for navigating vessels drawing 3 feet 6 inches. In order therefore to give the *Fossdyke* this necessary addition, and at the same time to drain

drain the lands in question without detriment to any other, we propose a scheme founded on the following facts.

1st. That from the surface of the river *Witham*, at the lower mouth of *Sincil Dyke*, to the surface of the water of *Brayford Meer*, when at its ordinary summer's height, is a rise of 14 inches; but from the surface of the river at *Stamford* to the same place, is a rise of 1 foot 7 inches and a half; and from the surface of the *Brayford Meer*, to the surface by *Bailey's Sluice*, is 2 feet $5\frac{1}{2}$ inches.

2d. That from the surface of *Brayford Meer*, to the surface of the river *Witham*, at the upper mouth of *Sincil Dyke*, which runs under *Bargate Bridge*, is a rise of 1 foot 6 inches.

3d. From the surface of *Brayford Meer*, to the surface of the river *Witham* at *Brace Bridge*, is a rise of 3 feet 2 inches.

4th. From the natural stanch of *Brayford Head*, to the bottom of the river at *Brace Bridge*, forming a natural stanch, there is a rise of 2 feet 6 inches.

5th. That from *Brayford Head*, to the bottom of *Sincil Dyke Drain*, at its highest part, near *Bargate Bridge*, is a rise of 1 foot $7\frac{1}{2}$ inches; and from *Brayford* to the mean highest bottom of the *Gowt Bridge Drains*, is 1 foot $3\frac{1}{2}$ inches.

N. B. At the time of this view, the *Sincil Dyke* and two *Gowt Bridge Drains* were all running about 3 inches over their highest points.

6th. We found, from our levels and observations, that all the low grounds adjoining upon the *Till*, are on so high a level above the surface of the *Fossdyke*, that they will have a drainage therein on the decline of floods, except about 40 acres, contained in a narrow screed by the old course of the *Till* side, from *Haddow Bridge*, about half a mile upwards, the lowest part of which we found 13 inches above the surface of the *Fossdyke*, and about 20 acres more laying in a flade a little higher up, on the north side, the lowest part of whose surface was 9 inches only above the *Fossdyke*; we also found that the only conveyance for the *Till* opposite this flade, was an artificial cut or ditch, about 3 feet and a half wide in the bottom, and at this time quite dry.

7th. That having examined the several drains that fall into the *Foffdyke*, west of the *Till*, we find that the bottom of *Dodington Drains* (by its tunnel) is 1 foot 6½ inches higher than the surface of the *Foffdyke*; *Thorney Drain* bottom, near the tunnel, is 6 inches above the said surface of the *Foffdyke*; but the bottom of the said drain, which rises gradually at about $\frac{3}{4}$ of a mile distance therefrom, is 4 feet higher than the same. The bottom of the first drain on *Kettlethorpe Moor*, near its tunnel, is higher than the surface of the *Foffdyke* by 3 feet 2 inches, the 2d by 1 foot 10 inches, and the 3d by 2 feet 2 inches; the bottom of the drain between *Kettlethorpe* and *Fenton Moor*, by its tunnel, is 1 foot 1½ inch, and that on *Fenton Moor* is 1 foot 7 inches higher, by its tunnel, than the surface of the said *Foffdyke*; and all the said drains rise considerably, as they advance into the land, and the said land is also in general considerably higher than the bottoms of the said drains, so that it is evident that none of these drains, nor the lands through which they pass, can be affected by a rise of 10 inches in the *Foffdyke* above the surface it then had, viz. 4 inches and a half above *Brayford Head*.

SCHEME for a general drainage and navigation.

1st. TO imbank both sides of the *Foffdyke*, where wanting, from *Brayford Meer* to the river *Till*, making all good, 5 feet higher than *Brayford Head*, (which, as the flood waters of the *Witbam* are proposed to be kept out of this part of the river, will be sufficient) and cutting off all communication with *Swan* and *Cuckoo Pools*.

2d. To scour out and enlarge *Sincil Dyke*, from its lower mouth near *Stamp End*, to the place where the first or northernmost *Gowt Bridge Drain* falls into the same, bringing up the bottom upon a dead level with the bottom of the river *Witbam* at *Stamp End*, making it 25 feet wide at bottom, with proper slopes. Then to scour out and enlarge the said *Gowt Bridge Drain*, from the said *Sincil Dyke* to the *Witbam*, continuing the bottom thereof upon the same dead level, and 15 feet broad, with proper slopes or batters; and to continue the same underneath the *Witbam*, by means of an underground tunnel or fox, 14 feet wide and 3 feet deep, with pointing doors on the east end, and draw doors on the west end thereof: the river *Witbam* to be entirely banked off from falling into this drain. A new drain of the same depth and capacity to be continued from the *Fox* to such part of *Swan Pool* as is as deep as the drain.

A drain

A drain of the same dimensions to be continued from *Swan Pool* to *Cuckoo Pool*. The ground taken out of the new cuts from the *Witham* to be disposed of bank-fashion, leaving forelands of 3 feet on each side of the cuts.

3d. To strike out a drain from *Swan Pool*, or from any point of the drain before mentioned, between *Swan Pool* and *Cuckoo Pool*, that shall be in a proper direction for crossing the *Foffdyke*, and to pursue the same to *Bishop Bridge*. This drain should be 14 feet bottom, with proper slopes, and to rise from the aforesaid dead level one foot between *Swan Pool*, or the point aforesaid, and *Bishop Bridge*; the said drain to communicate under the *Foffdyke* by means of a subterraneous tunnel, or fox, of 12 feet wide and 3 feet high; the earth of the cut from *Swan Pool* to the fox to be disposed of bank-fashion, with forelands of 3 feet.

N. B. A bridge will be wanting over this drain on *Lincoln Common*.

4th. To erect a lock with 2 pair of gates, upon the passage between Mr. ELLISON'S wharf and *Brayford Meer*, the gates to be pointed towards *Brayford Meer*; the whole to be built high enough to pen the water of the highest floods of the *Witham* from flowing into the *Foffdyke*.

5th. To scour out the river *Witham* where wanting, from *Brayford Meer* to *Brace Bridge*, and to embank the same on the west side, so as to be flood proof, and continuing the same on the south west side of *Brayford Meer*, to join the south side of the said lock; and to construct a similar bank on the north side of the said lock to the high land on the north side of *Foffdyke*, making the said banks 30 feet seat, 6 feet top, and 6 feet high; the river between *Brayford Meer* and *Brace Bridge* to be made at least 36 feet wide, and its bottom so deepened as to form a regular inclined plane one foot deeper than the present level of *Brayford Head* at that end thereof, and of the present depth at *Brace Bridge*. The bank to be formed partly from its back drain 10 feet wide at top, 4 at bottom, and 3 deep; the rest from the said widening or deepening the river, and to be placed 40 feet from the border of the river.

6th. To further scour out and enlarge the *Sincil Dyke* between the two lower mouths of the *Gowt Bridge Drains*, so as to be of the same dimensions as before specified for the lower part thereof, and from the lower mouth of the second or southernmost *Gowt Bridge Drain*, to scour out and enlarge the *Sincil Dyke* to its upper mouth at the river *Witham*, so as to be $12\frac{1}{2}$ feet bottom, with proper slopes, and the bottom to be carried nearly upon

upon a dead level from the said point to the river *Wisham*. And in like manner and proportion the second or southernmost *Gowt Bridge Drain* to be scoured out, and enlarged, from the said point to the river *Wisham*, and to erect two staunches; one upon the upper mouth of the *Sincil Dyke*, the other upon the upper mouth of the said *Gowt Bridge Drain*, both opening into the river *Wisham*: the *Sincil Dyke* staunch to be gauged to 1 foot 4 inches higher than the present level of *Brayford Head*; that is lower by $3\frac{1}{2}$ inches than the highest part of the present bottom of the said drain, and the *Gowt Bridge* staunch to be gauged one foot $2\frac{1}{2}$ inches above *Brayford Head*; that is one inch lower than the medium of the two *Gowt Bridge Drain* bottoms; the said staunch to have a clear waterway of $12\frac{1}{2}$ feet each, and their cills to be laid as low as the bottoms of their respective drains.

7th. To erect a staunch at or near *Lincoln High Bridge*, on the west side thereof, the top of which to be gauged to 10 inches above the level of the present *Brayford Head*, and to be filled up with doors capable of allowing a clear water-way of $15\frac{1}{2}$ feet at least, and the cills of these doors to be laid at least 2 feet 8 inches below the level of the present *Brayford Head*; after which, the said shoal of *Brayford Head* to be removed, and the whole contents of the river, between *Brayford* and *Lincoln High Bridge*, to be taken away as deep as the cill of the said staunch.

N. B. If instead of erecting the said staunch at the *High Bridge*, it be erected 100 feet to the west of the said bridge, with a pair of doors pointing towards *Brayford Meer*, it will form the upper gates of a lock, for making a communication between the *Fossdyke* and intended navigation from the *High Bridge* to *Boston*.

8th. To scour out, enlarge, and embank the *Till*, from its junction with the *Fossdyke* at *Haddow Bridge*, to about 1 mile above the same, so as to be capable of sustaining and confining the greatest floods within its banks, and to lay a small subterraneous tunnel of about 6 inches square under the same, to convey the down-fall and soakage waters from the low grounds laying west thereof, into *Burton* main drain, by which they will be drained in conjunction with *Carlton* and *Burton Fens*, &c. without any annoyance thereto.

N. B. It is proposed that the said cut shall be at least 12 feet wide at bottom, and its banks 5 feet higher than *Fossdyke* surface at low water.

9th. The gauged bar of *Torksey Lock*, (being $10\frac{1}{2}$ inches in height) to be removed, and the framed bar to become the gauge at *Torksey*.

10th. To

10th. To erect a pillar of stone, in or by the side of *Brayford Meer*, whose top to be 1 foot 2 inches above the level of *Brayford Head*; to be so placed that the water thereof may flow freely round and upon the said stone, with a set-off or conspicuous mark, 1 inch below the said top.

The OPERATION of the foregoing Constructions.

1st. AS there appears, from the facts before stated, to be a fall from the surface of *Brayford Meer* to the surface of the river *Wisbam*, at the lower end of *Sincil Dyke*, of 14 inches in its common summer's state; and that from the lower end of *Sincil Dyke* to *Stamp End* there is a further fall of $5\frac{1}{2}$ inches, chiefly owing to the obstructions of the river *Wisbam* between those two points, and also a yet further fall from thence to *Baily's Sluice*, of 10 inches; it follows, that whenever the Commissioners for the navigation between *Lincoln High Bridge* and *Boston* shall be pleased to execute this part of their undertaking, according to the act, that there will then be a much more considerable fall obtained: or, in the mean time, if they will suffer the drainers above *Lincoln* to deepen the river between *Stamp End* and *Sincil Dyke*, that then this $5\frac{1}{2}$ inches shall be added to the former 14 inches, so as to make 1 foot $7\frac{1}{2}$ inches fall from *Brayford Meer* to the lower mouth of *Sincil Dyke*. However, not to build this scheme upon the probable execution of another, we will, for the present, suppose every thing within that act to stand as it now does, still there will be a fall of 14 inches gained to *Brayford Meer*; and since the general surface of the low grounds (before specified) that drain into *Brayford Meer* were from a foot to 18 inches above the surface of that meer, at the time of this view (*Brayford Meer* being then $1\frac{1}{2}$ inch higher than its lowest state) it follows, that there will be a fall of above 2 feet 6 inches from the general surface of the low lands to their out-fall at *Sincil Dyke* tail; and as the flood waters of the *Wisbam* (which, for want of a sufficient discharge at *Lincoln*, have chiefly contributed to the overflowing of the same) will be held off by the proposed bank from *Brayford Meer* to *Brace Bridge*, there is no doubt but that the fall above mentioned will be sufficient for the general drainage of the low grounds aforesaid. It is true that some places, within the low grounds afore specified, lay lower than the general surface by several inches; but as the quantities so circumstanced are of no considerable extent, and as those very pieces will, by the execution of this scheme, be in better condition, as to drainage, than the greatest part of the low grounds now are, no reasonable objection can be

be drawn against the scheme in general from those particular places ; for as to the low flade of the old *Till*, between *Cuckoo Pool* and *Saxelby Pasture*, it may be provided for by carrying the main drain through it, and will, of consequence, be most early in receiving benefit ; and yet this flade will, at a medium, lay 2 feet, and its very lowest parts next *Cuckoo Pool* 19 $\frac{1}{2}$ inches above summer's water, even supposing nothing was to be done below the tail of *Sincil Dyke*..

2d. With respect to the low grounds laying upon the *Till*, the *Fossdyke* water being raised 10 inches by the stanches at *Lincoln High Bridge*, will pen 10 inches upon the mouth of the said river in dry seasons, at which time it has no currency ; but as we don't find any of those grounds will be affected thereby, except the small quantity before specified, and as in times of rains and floods, or whenever the water coming from the *Witham* would, in its present condition, rise 10 inches above its lowest state, (which, as has been shewn before, is the greatest part of the year) the *Till* will have a much better out-fall than it now has ; for, in the first place, as the *Witham* waters (which at present rise upon them near 4 feet in times of floods) will be entirely shut out from the *Fossdyke* whenever they would over-ride the same, by reason of the lock near *Brayford Meer*, and banks mentioned in the 5th article, as those waters themselves will be much sooner discharged than at present by the proposed stanches, as the gauge bar at *Torksey Lock* will be removed ; and as it is also proposed to confine the flood waters of the *Till* with banks of a sufficient height and strength to sustain them till they are fully discharged into the *Fossdyke*, the low grounds on each side the said *Till* can then be no otherwise annoyed than by the down-fall and soakage waters, which will be very inconsiderable, as the earth for making the said banks is of a strong and tight texture, and as an ample provision for carrying off these down-fall and soakage waters is made by the subterraneous tunnel to be laid under the *Till* into *Burton Drain*, it follows, that upon the whole, the discharge of the *Till* waters will be considerably facilitated and improved, and the drainage of the low grounds under consideration, that lay thereupon, will be completed.

3d. The grounds, west of *Saxelby*, which drain into the *Foss*, will in like manner have the surface of that river raised 10 inches upon the tail of their drains, in dry seasons ; but as we find none of them that will be affected by that rise, (very little by double, nay even treble) and as the *Foss* will no longer be raised by the *Witham* floods, and those floods sooner run off by the gates of the proposed stanches, it will be kept at a more constant height, being no otherwise affected than by the influx of their own and the *Till* waters, which will find their way either into the *Trent* or *Witham* waters, as soon as either river is so settled as the *Foss* water will over-ride them ; so that upon the whole, these

these lands being freed from the high floods, which principally annoy them, will be greatly benefited, and ought in strictness to contribute towards the making of the said lock and bank.

4th. The proprietors of lands above *Brace Bridge* will also receive benefit by this construction; for since there is 18 inches fall from the upper mouth of *Sincil Dyke* to *Brayford Meer* at ordinary seasons in summer, it is plain that an additional pen at the said meer will not sensibly affect the level of the water at the entrance of *Sincil Dyke*; on the contrary, when the widening and deepening of the River between *Brayford Meer* and *Brace Bridge* is performed, the water will then run off lower than at present; and since the tops of the staunches at *Sincil Dyke* and one of the *Gowt Bridge Drains* are to be lower than their respective bottoms now are, and the capacities of those drains greatly enlarged, it is manifest that though the staunches were never to be drawn at all, the water would have a better passage than it can now have; but as the preservation of the banks, proposed in Article 5. of the scheme, depends upon drawing the staunches, the proprietors of the aforesaid low grounds will not be wanting in drawing them when necessary, which will afford a great easement to the passage of the water far beyond any thing they have ever had: and, for the prevention of disputes between the land owners and navigators, it is proposed that whenever the water of *Brayford Meer* covers the stone pillars proposed in Article 10. that the gates of the staunches shall be drawn, or so many and so much as shall be found necessary to reduce the waters 1 inch below the top to the mark aforesaid; and whenever the water shall settle below the said mark, then the gates of the said staunches to be shut down, or so many and so much as to prevent its falling below the said mark, which business will be regularly done by a person properly appointed and authorized for this purpose.

5th. The undertaking for drainage of the fens, and navigation between *Lincoln High Bridge* and *Boston*, will also be benefited by this scheme; for since the great object of that scheme was to preserve the living and flood waters, particularly those of the *Witham*, for scouring of the out-fall, by this means they will be preserved, and brought down by the readiest passage, instead of being spread over the fens and low grounds above *Lincoln*, by which their force is broke, and a great part thereof evaporated by the sun and winds. It is true that the *Fossdyke* being kept up 10 inches higher, will expend somewhat more water in the passage of each vessel; but, on the other hand, the communication between the *Fossdyke* and the *Swan* and *Cuckoo Pools* being stopped, the evaporation from the extended surface thereof will thereby be saved; and the matter being reduced to a fair calculation, it appears that this evaporation is greatly more than sufficient to

supply the difference of lockage, leakage, and soakage, that will probably arise from an increase of height of 10 inches in the *Fossdyke* surface.

6th. This scheme will also be of great benefit to the navigation of the *Fossdyke*, not only in giving the necessary quantity of water to render it compleat in all seasons, from the river *Trent* to *Lincoln High Bridge*, but in excluding such extra quantities of water, as in time of floods not only annoy the navigation, but the lands adjoining thereto, which inconvenience must have subsisted ever since this cut was originally made, and consequently must always have been the foundation of disputes and dissatisfactions between the navigators and land owners thereto adjoining; and upon the present scheme it appears that the interest of both parties coincide, it is greatly to be wished and hoped that they may as heartily join in the expence of executing the same upon an equitable footing; and lest any jealousy on the part of the land owners should obstruct the execution of a project so much to their advantage, as supposing it more calculated to serve the navigation than themselves, we think it expedient to declare, that nearly the same advantages can be procured to the navigation as will be obtained in the scheme before specified, without prejudice to the present state of the land owners drainage, and that to accomplish as good a drainage, as is proposed by this scheme, will cost the land owners considerably more, than if done conjunctly with the proprietors of the navigation.

An ESTIMATE of the works mentioned in the preceding scheme.

Article 1st.	To making good both banks of the <i>Fossdyke</i> , from <i>Brayford Meer</i> to <i>Saxelby Pasture</i> , opposite the <i>Till</i> ,	£.	s.	d.
	- - - - -	463	15	0
Art. 2d.	To scouring out and enlarging <i>Sincil Dyke</i> , from its lower mouth to the first <i>Gowt Bridge Drain</i> (including contingencies),	172	15	8
	To scouring out the first <i>Gowt Bridge Drain</i> , from <i>Sincil Dyke</i> to the <i>Witbam</i> , and the contingency of under-pinning the arches under which it passes,	53	0	0
	To making and laying the fox under the <i>Witbam</i> ,	208	12	0
	To making a new drain from the fox to <i>Swan Pool</i> ,	63	2	0
	To making a drain from <i>Swan Pool</i> to <i>Cuckoo Pool</i> ,	84	0	0
Art. 3d.	To making a new drain from or near <i>Swan Pool</i> to <i>Bishop's Bridge</i> ,	145	4	0
		Carried over	1190	8 8

	£.	s.	d.
Brought over	1120	8	8
To making and laying the fox under <i>Fossdyke</i> ,	190	0	0
To making a new hauling bridge over the drain, and a waggon bridge for the road to <i>Pywipe</i> inn,	40	0	0
Art. 4th. To constructing a lock between Mr. <i>Ellison's</i> wharf and <i>Brayford Meer</i> ,	400	0	0
Art. 5th. To scouring out and enlarging the river <i>Witbam</i> , and embanking the same on the west side from <i>Brayford Meer</i> to <i>Brace Bridge</i> , and to embanking <i>Brayford Meer</i> on the south-west side, from the north end of the aforesaid bank to the lock, and from the lock across the high land in the north, including the south drain,	587	19	0
Art. 6th. To scouring out and enlarging <i>Sincil Dyke</i> , between the lower mouths of the <i>Gowt Bridge Drain</i>	12	0	0
Scouring out and enlarging <i>Sincil Dyke</i> from the second <i>Gowt Bridge Drain</i> to the <i>Witbam</i> , and the contingency of under-pinning Bargate bridges,	63	5	0
To scouring out and enlarging the second <i>Gowt Bridge Drain</i> , from <i>Sincil Dyke</i> to the <i>Witbam</i> , and the contingency of under-pinning the arches under which it passes,	42	10	0
To erecting two stanches, one at the upper mouth of each of these drains, at 180 <i>l.</i> each,	360	0	0
Art. 7th. To constructing a fixed stanch, with draw-door, at or near the <i>High Bridge</i> , at <i>Lincoln</i> ,	200	0	0
To scouring out <i>Brayford Head</i> , and deepening the river from <i>Brayford Meer</i> to <i>Lincoln High Bridge</i> , including the rebuilding of walls,	195	0	0
Art. 8th. To deepening and enlarging the <i>Till</i> , from <i>Haddow Bridge</i> one mile upwards, so as to be 12 feet wide at the bottom, and making strong and effectual banks on each side, at least five feet above the low water in the <i>Fossdyke</i> ,	168	6	0
To making and laying a subterraneous tunnel under this dyke and banks, 6 inches square within,	4	0	0
To making a catch-water drain and bank on the lower side, at the upper end of this new cut, to reach the high land on each side the same, which will conduct all the flood-water therein,	8	5	0
Art. 9th. To taking away the gauge-bar at <i>Torksey Lock</i> ,	0	5	0
Art. 10th. To erecting a stone pillar for a gauge height in <i>Brayford Meer</i> ,	5	0	0
Art. 11th. To supervising, and unforeseen contingencies, at 10 <i>l.</i> per cent.	350	0	0
	£.	3816	18 8

Doncaster, October 16, 1762.

JOHN GRUNDY.
J. SMEATON.

We come now to give an answer to the following question, communicated to us by Mr. AMCOTTS.

“ Mr. GOLLMAN desires to know if the *Sincil Dyke* and the *Gowt Bridge Drains* were to be scoured out and deepened to the depth of the new intended river below *Lincoln*, with gates erected at the upper end 2 inches higher than the present height of *Brayford Head*, a channel to be made from those places into *Brayford Meer*, to communicate with the *Fossdyke*; the gates to be opened at the time of floods, the shoal at *Brayford Head* to be removed, and gates or a ware to be erected by the side; the top of which to be 10 inches lower than the present height of *Brayford Head*, with a waste board to be placed thereon in dry seasons; what effect such a scheme would have on the *Fossdyke* navigation?” The scheme here proposed, in some respects, is the same as the scheme proposed by us, as before specified, but with this essential difference, that our scheme proposes to give the *Fossdyke* navigation an addition of 10 inches constant water above its lowest state, and a compleat drainage to the lands; the other to keep it constantly at its lowest state, with an imperfect drainage of the lands.

From the time the rains usually fall in *September* or *October*, to the running off and evaporating the flood waters in *May*, the *Fossdyke* navigation is generally as compleat as can be wished for; but were the flood waters run off by the proposed gates as they come down, the *Fossdyke* would never be above its lowest gauge, except at the top of high floods; which, as they would be uncertain, would be of little use to the navigation: for as *Brayford Head* is proposed to be reduced 10 inches, except in dry seasons, this would constantly run off the common current waters; and perhaps often more than that after the gates had been drawn, so that at those times the *Fossdyke* would be reduced to a lower state than it ever can be at present, all which in consequence would be a great detriment thereto; besides, no man as a navigator would chuse to subject his water to the mercy or misconduct of others, or the want of necessary repairs of gates, stanches, or other works, without any prospect or probability of any advantage arising therefrom.

And with respect to drainage, the scheme proposed by the aforesaid question is extremely imperfect, almost all the requisites for a compleat one being omitted, that is to say, the necessary imbanking of the rivers, &c. to keep out the flood and barrier waters, and the proper means of carrying off the downfall and soakage to a surface sufficiently below the soil of the lands to be drained; for nothing more is thereby proposed towards accomplishing these great ends, than forming stakes to ease the flood waters, (which is as fully and amply provided for in our scheme as in this) but very far from totally removing

moving their effect upon the low lands in question ; so that, after the execution of such a plan, the low grounds of *Boatbam, Skellingthorpe, Saxelby, Lincoln, Burton, Carlton, &c.* would yet be liable to be overflowed in all wet seasons, and in dry ones the proposal itself points out no advantage in drainage.

Doncaster, Oct. 16, 1762.

JOHN GRUNDY.
J. SMEATON.

Concerning the drainage of the low grounds of *Torksey* and *Fenton*, which drain by *Torksey Bridge Sluice*.

AS the drains of those grounds have no communication with the *Fossdyke*, till below *Torksey Lock*, their out-fall is in effect into the *Trent*, and therefore it is of no concernment to them what the height of the *Fossdyke* surface is between *Torksey* and *Lincoln*.

Torksey Bridge Sluice (the out-let) lays on the south side of the *Fossdyke*, and also the drain leading thereto, which extends eastward about a furlong, and there divides, one branch turning to the right through *Fenton Moor*, the other to the left through *Torksey* low grounds, which laying on the north side of the *Fossdyke*, communicates by means of a subterraneous tunnel or fox, each drain having a separate sluice near the point of partition, which shuts reciprocally in case either water should over-ride the other. Each of these drains receives the down-fall waters from an extensive tract of country, and in consequence, in times of great rains, when the *Trent* is so full as to keep shut the doors of *Torksey Bridge Sluice*, those waters overflow their respective drains, and consequently the lowest lands near their out-fall, and if the rains are violent and lasting, and the *Trent* continues high, as it sometimes does for weeks together, the waters, all this while accumulating within, rise to a great bulk and height. As therefore the cause must always remain, the effect will do so too; the only thing that can be done, in the present case, is to give the water a passage sufficiently free, that whenever the *Trent* becomes lower than the waters within, they may run off as soon as may be. Those ought to be the views of them who undertake the drainage of those tracts of land. The only question that relates to the *Fossdyke* is, whether the proprietors thereof have made provision for discharging

charging those waters as amply as the proprietors of lands have made for themselves to bring the water thither*.

The sluice at *Torksey Bridge*, and the fox under the *Fossdyke*, are works constructed by the undertakers of the *Fossdyke*; the sluice at the tail of *Fenton Drain*, and that at the tail of *Torksey Drain*, leading into the fox, are old works constructed by the land owners to serve their own occasions. The sluice at *Torksey Bridge* consists of one arch or tun of 7 feet wide, which having a staple-post of 1 foot wide in the middle, forms it into 2 apertures of 3 feet wide each, which are shut by two falling doors; the floor of this sluice lays lower than *Fenton Sluice* by 1 foot 9 inches, lower than the sluice entering the fox by 1 foot, and lower than the lowest lands to be drained thereby 2 feet 1 inch. The width of *Fenton Sluice* is 2 feet 11 inches; the sluice leading to the fox consists of two doors, which are 2 feet 1 inch wide each. The width of the fox is 2 feet 10 inches by 2 feet high, and the entry thereof lays 8 inches lower than the threshold of the sluice adjoining. 1st. The question is therefore, whether *Torksey Bridge Sluice* is equal to the capacity of *Fenton* and *Torksey Fox Sluice* taken together, in point of discharging water; and, 2d, whether the capacity of the fox is equal to the capacity of the sluice leading thereto. Having subjected this matter to calculation, we find that at a mean height of the flood waters upon *Torksey* (which is the lowest lands) that *Torksey Bridge Sluice* will run more water than *Torksey Fox Sluice* and *Fenton Sluice* put together, by above 200 cube feet in a minute, which arises from its laying so much lower; but that, in the like case, the fox will not run so much water as the sluice adjoining thereto; but that if another equal tunnel is thereto added, that the capacity of the two will exceed the capacity of the said sluice by above 500 cube feet in a minute. We therefore recommend it to the *Fossdyke* proprietors to add another fox of equal capacity, or to double the capacity of the present; but as we are of opinion the foundation of the grievance does not so much consist in want of capacity in the fox to discharge the water, as in the sluice itself to run it off, *low enough*, we are of opinion, that at the same time the capacity of the fox is enlarged, that the land owners should lay the threshold of this sluice as low as the out-fall sluice at the bridge, and that the entry into the fox should be made conformable thereto. In this case, the mean capacity

* In constructing works by act of Parliament, if ample provision is made for the preservation of private property, to the satisfaction of the proprietors at the time, that if afterwards those proprietors extend their views in order to improve their property, that the public undertakers at their own expence to make all such alterations in their works that the land-owners should think fit; if this was the case, a public undertaker would never know when he had done.

for discharging water will not only be doubled, but with the advantage of running it 1 foot lower than at present, which will be above 2 feet lower than the lowest lands that drain thereby.

N. B. It must, however, be considered, that it is but lately that a new tunnel of 2 feet wide at *Harrow Head Bridge* has been added; the whole capacity of that bridge was before that time only one tunnel of 2 feet 2 inches wide, the paved floor whereof lays at least six inches higher than the sluice at the fox; and as the bulk of the water that comes to that sluice comes through this bridge, it must be acknowledged that the capacity of the fox to discharge water at the time it was made was superior to the capacity of this bridge to let down the water to it.

The meeting of the *Torksey* and *Fenton* waters, in a direction nearly opposite, is a manifest incongruity; but as the place of meeting is pretty deep, and wider than the rest, it forms in some measure a reservoir common to both, and, if perfectly so, it would signify little in what direction the water comes in; but as it appears to us, that as the land drains and sluice lay lower on the *Torksey* than on the *Fenton* sides, that the *Fenton* waters will generally over-ride the *Torksey*: this will deserve a remedy that will also cure the other defect at the same time. We therefore propose that a new tun of 4 feet wide and 3 feet high, with one door, to be added to the present sluice at *Torksey Bridge*, on the south side thereof, and making a partition between the old and new tuns, and to bring the present common drain in an oblique direction to the new tun, and to carry a new drain from behind the said partition, from the old sluice to the tail of the fox, stopping the present communication near *Fenton Sluice*; by these means the waters will be kept quite separate, which will be a great improvement to the present drainage of the low grounds under consideration; and as it will lay the foundation for completing the drainage thereof, as far as nature will allow, in our opinion, the land owners ought to be at part of the expence of the aforefaid new sluice and drain. An obvious mistake has also been committed in turning the tail drain leading from *Torksey Bridge Sluice* into *Foss*, below the lock, at a square elbow; but if it be considered, that this drain, being wider than the clear water-way of the sluice by three feet, and deeper than the floor thereof, the velocity of the water is so much less on account of a greater capacity, that the ill effect of this inconsistency is not, in reality, so great in the present case as it may seem; however, as this drain must be widened near the sluice, on account of the new tun, to give a freer passage to the water, and to remedy this defect both at once, we advise the turn of the said drain to be made by a quarter round instead of a square elbow.

JOHN GRUNDY.

J. SMEATON.

Doncaster, October 16, 1762.

To the gentlemen assembled at a general meeting on the 2d day of September, 1782, for considering of a plan of improvement of the navigation of the river *Fossdyke*, and for improving the drainage of the lands on each side the said river.

GENTLEMEN,

SINCE my arrival at *Lincoln* on Thursday evening last, (as desired by Mr. LYON) I have diligently employed myself, in conjunction with Mr. CARLTON, and Mr. PILLEY, agent for Mr. ELLISON, who were appointed to conduct me, in reviewing the different parts of the extensive scheme of drainage and navigation, that was formed by Mr. GRUNDY and myself in the year 1762, in order to prepare myself to assist you, gentlemen, in the reconsideration thereof.

It is a subject indeed so extensive, that the time has been fully employed in going over some of the most material and leading parts thereof, and it will necessarily take a further length of time to enter into that accurate and digested consideration that it had from Mr. GRUNDY and myself at the time abovementioned, being now 20 years ago. But, as upon this revival, I find a very striking difference in the situation of the leading circumstances attending this business, I think it necessary to lay those open to your consideration, because, unless some means are found, by which the impediments, that since that time have been placed in the way, can either be removed or avoided, it seems fruitless to enter into any scheme for the general drainage of the low grounds west of *Lincoln*: for it does not appear to me, that as things now stand, any such material improvement can be made therein, as shall be likely to answer the cost of doing it.

When the scheme of 1762 was under consideration, the *Witham* navigation act from *Lincoln* to *Boston* was then subsisting, with a clause therein, that no staunch or land-door should be erected between *Walsingham Ferry* and *Lincoln High Bridge*, which should not be at least 2 feet below the lowest grounds in *Canwick Ings*, as by reference to the act will more fully appear. At present, I find a lock and a staunch below the lower mouth or out-fall of *Sincil Dyke*, which by the former scheme was to be the out-fall of the drainage waters of the lands west of *Lincoln* into the river *Witham*, the top of the gates or doors of which staunch is higher than the surface of the said lowest grounds of *Canwick Ings*, and consequently they are, as it appears to me, full 2 feet higher than
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according to the said clause they ought to be, (the doors or gates of the lock being still higher) and the top of the gates or doors of the said staunch being full as high as *Brayford Head* was in 1762. The fall for the drainage waters from *Brayford Meer* to the lower mouth of *Sincil Dyke* is now taken away and lost, the water being now so near upon a level at the two said points, as to be totally insufficient towards any material improvement in point of drainage.

In order, therefore, to recover the fall for the proposed drainage waters that then subsisted, it appears to me absolutely necessary, either to remove the said staunch, whereby the waters may have their natural descent in its ancient course through the city of *Lincoln*, or to carry the out-fall drain so far below the limits of the *Sincil Dyke* as to pass through some part of *Canwick Ings*, and fall into the present course of the river *Witbam* below the said lock and staunch; that is, where the same, on mature consideration, shall be deemed the most eligible.

The latter way appears to me at present preferable, not only as it would not interfere with the present navigation, but the drainage waters would be less liable to be over-ruled by the living waters of the *Witbam*.

I am, Gentlemen,

Your most humble servant,

Lincoln, September 2, 1782.

J. SMEATON.

To the Gentlemen that attended a general meeting on the 2d day of September, 1782, at the *Rein Deer* at *Lincoln*, for considering of a plan of improvement of the navigation of the river *Fossdyke*, and for improving the drainage of the lands on each side of the said river.

The REPORT of JOHN SMEATON, Engineer, upon the improvement of the navigation of the river *Fossdyke*, and for improving the drainage of the low lands on each side of the said river.

IN the year 1762, Mr. GRUNDY and myself were employed by Mr. ELLISON to form a scheme for the improvement of the *Fossdyke* navigation, and at the same time to improve the drainage of the low grounds west of *Lincoln*, of which business we acquitted ourselves by our joint report, dated the 16th of October of that year; contrariety of opinion among the parties interested at that time prevented the execution of the scheme then proposed.

In August last I was invited to reconsider the said scheme, and to assist the gentlemen interested in this business in forming such a one, as at this time should be useful and agreeable to all parties, and to attend their public meeting at *Lincoln* for that purpose upon the 2d of September last, which accordingly I did.

On reviewing the subject previous to this meeting, I perceived that upon supposition of the best possible drainage, compatible with the improvement and even *subsistence* of the *Fossdyke* navigation, that the scheme then proposed appeared now to me to be very complete upon the circumstances and situation in which things then were; but that at present, the case is so very much altered, that the very ground and foundation upon which we built the principal merit of the scheme, so far as it related to drainage, is now subverted; for the ultimate drainage of all the grounds in question being into *Brayford Meer*, and as at that time there subsisted a fall in dry seasons in summer from *Brayford Meer*, through the city of *Lincoln*, to that part of the river *Witham* where the tail of *Sincil Dyke* falls into it, of 14 inches, and a further fall then of $5\frac{1}{2}$ inches more to *Stamp End*, and which was still greater down to the point where *Bailey's Sluice Drain* falls into the same, it appeared to us, that the addition of this fall to the low grounds that then drained into *Brayford Meer*, when judiciously managed, would make the drainage thereof very complete. Nor were there at that time any reason to fear the loss of this fall, but
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rather an expectation of gaining more; for though the act of parliament for draining the lands, and making or improving the navigation from *Lincoln High Bridge* to *Boston*, had then passed; yet as the advantages that might in future possibly result from this fall to the city of *Lincoln*, and low grounds west thereof, were guarded by a clause, enacting that no staunch or land door should be erected between *Washingborough Ferry* and *Lincoln High Bridge*, which should not be at least 2 feet lower than the lowest grounds in *Canwick Ings*, there could then, in regard to this fall, be no apprehension of difficulty; but contrary thereto, on this view I found a lock below *Stamp End*, now called *Lincoln Lock*, accompanied with a staunch, erected across the river *Witham*, abreast of the said lock, and consequently below the tail or out-fall of *Sincil Dyke*, into the said river; the top of the said doors of which staunch was not only higher than the medium surface of the lowest grounds in *Canwick Ings*, and therefore full 2 feet higher than according to the said clause they ought to be, but also higher than the natural staunch of *Brayford Head* was in the year 1762, and occasioned a pen of the water in *Brayford Meer*, higher by $1\frac{1}{2}$ inch than it was at that period: in consequence, as in this state of things *Brayford Meer* is rather higher than lower than it was, and the fall that might have been required totally taken away and destroyed, it follows, as things now are, (*Brayford Meer* being still the ultimate out-fall of the drainage of all the lands in question) that no material improvement can be made therein.

These consequences I did myself the honour of laying before the gentlemen assembled at the meeting of the 2d of September last, and withal observed, that unless either *Lincoln Lock* and *Staunch*, as it now stands, can be removed, or a new out-fall procured for *Sincil Dyke*, so as to fall into the *Witham* below the said staunch, it will be to no purpose to think of any schemes of drainage that will be likely to be attended with benefit equal to the expence.

These matters being fully considered by the gentlemen present, and seeing difficulties in either way, and it being the general sense of the meeting, that it would be a considerable improvement to their low grounds, if they could more early in the spring be cleared and ridded of their water, without destroying the navigation through *Lincoln*, I then observed, that on supposition *Lincoln Staunch* and *Lock* was removed still higher up the stream from its present place, above the tail of *Sincil Dyke*, I did not doubt but to be able to draw up a scheme that would not only preserve, but greatly improve the navigation through *Lincoln*, greatly benefit the drainage of the lands without imbankments upon the *Witham*, but also give every competent improvement to the *Fossdyke* navigation, and that by expedients to which I could not see any reasonable objection.

This scheme, after fully and deliberately considering, I now beg leave to propose.

The lands at present under consideration are the general reservoir of the waters that in great floods are brought down by the river *Witham* from the upland country, through a course of above 40 miles, the passages for which through *Lincoln*, relative to the fall it has, are at present so very inadequate to the discharge of this water as fast it comes, that it extends over a vast tract of ground of many miles square.

In the year 1762 it was known to have rose above its summer drainage height about 4 feet perpendicular, but upon this view this water, from marks that were shewn me, its height had been more than 5 feet 9 inches above the former mark, which shews that the banks necessary to restrain and carry off so great a body of water as fast as it comes would be required of such height and strength, that I am of opinion (with the land owners) it would be not only very difficult and very expensive to confine, but be matter of objection to the drainage of the lands upon the *Witham* below *Lincoln*.

In a dry season the lands in question become compleatly drained by the present outlets, but as the ultimate level of *Brayford Meer*, at which the fresh waters of the *Witham* can be discharged, is but a few inches lower than the lowest grounds proposed to be drained, when the top waters are so much run off, as that the drainage is almost compleated, the quantity capable of being then discharged but so little exceeds the influx of the *Witham* from the higher country, that was it not for the joint action of the sun and winds, the surface of these lowest tracts would never become dry, so as to be capable of any good produce of vegetation; but if when the top waters are run off, and the whole surface reduced to the level of the present natural banks of the river and aqueducts, a discharge is provided, that now cannot run for want of level or fall, a very moderate discharge (that would signify but little in respect to the running off of the top waters) continuing to operate by itself separately, and independently of the river *Witham*, and appropriated wholly to the discharge of such internal waters as are left behind, after the flood waters are reduced within their natural banks; I say, such internal dead waters would very speedily be discharged when all communication with the living waters were cut off, though this new and separate discharge was not above half as much as the current of the river *Witham* in dry seasons.

It is obvious, that a meer removal of *Lincoln Lock's* staunch would not fully effect this business, even though *Brayford Head* was fully cleared, and the channel deepened through *Lincoln*, because still the *Witham* water would be obliged to pass through the
same

same channel; that is, it would pass through the preferable channel, in point of fall, while in common, and therefore would interfere with and over-ride the drainage waters at the very pinch when the drainage was wanted to be completed.

Furthermore, if the *Fossdyke* navigation was supplied with water by an aqueduct from an higher part of the river *Witham*, independent of *Brayford Meer*, and the out-lets of all such grounds as drain into *Fossdyke* east of *Saxelby*, or into *Brayford Meer*, banked off, (making *Fossdyke* itself a means of discharging the top waters when the whole country is over-pressed) then *Brayford Meer* may remain at its present height, and all impediments be removed between *Brayford Meer* and the first lock towards *Boston*, as low as to the floor of the water-way under *Lincoln High Bridge*, which would render the navigation through *Lincoln* much preferable to what it now is, as there would be 2 feet depth of water at such times and places where now there is no more than one.

THE SCHEME.

1st. To remove the lock called *Lincoln Lock* and its staunch, from its present place below *Stamp End*, to above the tail of *Sincil Dyke*, where there is a commodious opening to receive it, as will appear from a sketch of the manner in which it may be placed.

2d. To deepen that part of the river *Witham* that lays between the present place of the staunch, and the place where it is now recommended, so as to make it passable for any boats that can now come up to *Lincoln Lock*, and which will not require a deepening of above half a foot at a medium.

3d. To scour out *Sincil Dyke* to as great a width as it has ever originally been, from its tail or out-fall into the *Witham*, to the tail of the great *Gowt Drain*, bringing up its bottom upon the same dead level with the bottom prescribed in the last article, as necessary for navigation, and to as great a width as it will carry, after allowance of sufficient slopes.

4th. To dyke and scour out the great *Gowt Drain* to the greatest width it will bear, and still bring up the bottom upon the same dead level as prescribed for *Sincil Dyke*; but instead of opening a communication with the river *Witham*, to continue the said drain under the river by means of an under-ground tunnel four feet wide and four feet high clear water-way, with doors pointed towards *Sincil Dyke*. The floor of this tunnel to be laid so much deeper than the bottom of the *Great Gowt Drain*, that the river *Witham* may run in
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its present natural course above its arch, and that the work of the said arch be finished as high as that the river *Witham* may pass over it without raising its surface, in its ordinary or extraordinary state, upon a width of at least 30 feet. The west side wall next the low lands to be raised to a competent height to prevent the *Witham's* waters, in time of floods, from cascading over it; but the height of the east wall to be raised only one foot above the ordinary surface of the *Witham*, so that when there is a swell in the *Witham* above that height, it may cascade over into this *Gowt Drain*, which will then act as a flaker, according to its present intent, and make its way by *Sincil Dyke* to the *Witham*.

5th. To scour out *Sincil Dyke*, from the tail of the *Great Gowt Drain*, to its upper mouth at the river *Witham*, yet not to make an open communication with the river; but to prevent the river in dry times from taking its course that way, and to give it a competent passage through *Sincil Dyke* as a flaker drain, (to which use it has been apparently intended in its original formation) to construct a weir of 60 feet in length upon the crown, ranged along the east side of the river *Witham*, which, being immediately collected into *Sincil Dyke Drain*, can run no more water in high floods than the drain will and ought to contain: in time of dry seasons to be about one inch above the water's surface of the river, so as just to pen in all the water thereof, and upon a fresh rising above that to discharge a competent quantity, upon a moderate additional height, in virtue of the length of its crown.

6th. To effectually scour out the lesser *Gowt Drain*, and in like manner as the entry into *Sincil Dyke*, to be shut off by a weir of 45 feet long in the crown, conditioned and operating as *Sincil Dyke* in proportion to its size; but to allow for the natural fall of the river from *Sincil Dyke* to the entry of the little *Gowt Drain*, this weir to be gaged $1\frac{1}{2}$ inch lower than the former. And N. B. it will be proper to give all possible freedom and effect to these 2 flaker drains, because the *Great Gowt Drain* will not now serve this purpose except in floods.

7th. A drain to be carried from the said tunnel, at the head of the *Great Gowt Drain*, to *Swan Pool*, and to pass by or through the same, as shall be found most convenient and practicable in the execution; to be of 12 feet bottom, with proper slopes, and still carried on upon the same dead level. From thence the drain to pass forward upon a 10 feet bottom to a proper place, to divide into two branches; one tending towards *Cuckoo Pool*, and the interior parts of *Shellingborough*; the other towards a proper point of the *Fossyke*, to receive the *Burtan* and *Carlton*, &c. waters, from *Bishop's Bridge*, by a subterraneous tunnel under the *Fossyke*; all which said drains are to be carried on upon the same dead level as before prescribed.

8th. A

8th. A subterraneous tunnel to be laid under the *Fossdyke*, to communicate the water from *Bishop's Bridge*, of sufficient capacity to run the drainage waters without material loss of fall after the top waters are discharged; but as the laying a tunnel of this kind, the top of whose arch must be so deep below the common surface of *Fossdyke* as to clear the navigation, the construction of such a tunnel by the ordinary means in brickwork would require so much length of time as to be a great loss of tolls to the navigation, which, together with the actual expence, would lay too great a burthen upon the scheme I am proposing; I would therefore recommend the tunnel under the bottom of the navigable river to be made of cast iron. This to be made in proper lengths with flanches, by which they can with bolts be readily joined together; and I expect that a clear iron pipe of 2 feet 6 inches diameter would be very competent to this business, but that of 3 feet would put it beyond all doubt.

9th. From this tunnel a drain should (still upon the same dead level bottom) be carried to *Bishop's Bridge*, and that bridge rebuilt correspondent to such depth, the width of the drain's bottom to be 9 feet, and the tunnel of the bridge correspondent; from thence the drain to be carried forward, as a private work, into *Burton* and *Carlton* lordships; but still I would recommend, that whatever width may be taken for the bottom, that it be carried on upon the same dead level till it comes to the pinch of that drainage, which, according to Mr. GRUNDY, is in *Scuth Carlton* lordship, and that the ground in the lowest flade there is no more than $14\frac{1}{8}$ inches above *Brayford Head*, as in the year 1762, that is $8\frac{1}{8}$ inches above *Brayford Meer*, as I found it this year, 1782; from thence the main drains, as well as side drains bottoms, may be allowed to rise at discretion.

10th. I would recommend a drain to be continued from the former, at or near *Cuckoo Pool*, through *Skellingthorpe*, by way of the low flade of the ancient course of the *Till*, into *Saxelby Pasture*, till opposite *Saxelby Meadow*, on the north side of the *Fossdyke*, diminishing from a 7 feet bottom at *Cuckoo Pool*, to a 5 feet bottom at the said point in *Saxelby Pasture*; but still continuing the same dead level.

11th. Between Mr. *Ellison's* wharf and *Brayford Meer* to construct a navigation lock, with gates pointed towards the *Fossdyke*, shutting up all other communication between *Fossdyke* and *Brayford Meer*, except by a weir, as per next article.

12th. To make an aqueduct of 10 feet bottom, to take its water at the river *Witbam*, just above the *Great Gout* drainage-tunnel, and to pass to the *Fossdyke* at some convenient

convenient place opposite to or west of Mr. *Ellison's* wharf, in order to supply the *Fossdyke* with water; and, at a certain height, a weir or over-fall to be constructed, that all redundant water beyond the supply of the *Fossdyke* navigation may be returned into *Brayford Meer*, and so go to *Boston*; this ought to be 40 feet in length upon the crown.

N. B. This aqueduct necessarily intersecting the drain prescribed in the 9th Article, is to pass it, by a continuation of the tunnel, as an aqueduct bridge, to convey its water in a separate passage over the drain, and to be well imbanked on each side, so that it be never overflowed till the country is under water.

13th. To make a provisionary navigable staunch at *Brayford Head*, the gates whereof to be gauged to the same height that *Brayford Head* was in 1762, that the navigation into and upon *Brayford Meer* may not be dependant upon the staunch at *Lincoln Lock*, and the whole passage cleared from *Brayford Meer* to *Lincoln High Bridge*, as deep as the floor of the passage of the said bridge; and then if the trustees for the navigation from *Boston* to *Lincoln* think proper, in like manner, to clear away to the same depth east of the said bridge, there will be a clear navigation from *Brayford Meer* to the sea, equivalent in all parts passing *Lincoln* to that under *Lincoln High Bridge*.

N. B. In time of floods the gates of the *Brayford Head* staunch must be set open, as well as the doors of the *Lincoln Lock* staunch, for relief of the country west of *Lincoln*, in running off their top waters, as I am informed is very properly the present practice; but it should seem that the opening and shutting of these doors should be within the direction of the magistrates of the city of *Lincoln*, who, being most central, will more readily be apprised of, and see the necessity of the country.

14th. That for the general relief of the country west of *Lincoln*, and the more speedily to get rid of their top waters, which, as before, will continue to overflow the whole Country in the winter season, it will be very proper to embrace Mr. *ELLISON's* proposition of granting liberty for a side weir to be constructed of a proper height at *Torksey*; so that a part of the top waters may be run that way into the *Trent*, when the level of the *Trent* will admit thereof, as it often at such times does. This weir, however, should not be too low, that the *Witham* fens drainers may have no reasonable complaint of losing water to keep their out-fall clear; nor should it be too high, because, if so, it will be of little use in answering the purpose for which it is made; but it should be of considerable extent in length upon the crown, that when it does discharge it may do it with effect. It appears to me, that if it is made 100 feet upon the crown, its height 6 inches below the gauge

gauge bar of *Torksey Lock*, that is about $4\frac{1}{2}$ inches higher than the framed bar, it will answer all these purposes. This would be easily constructed, extending 100 feet eastward from the east end of the wharf wall, on the south side of *Fossdyke*; but as its discharge cannot be permitted to over-ride the *Fenton Drain*, the present south bank of the *Fossdyke* must be carried forward from the east end of the weir, between the weir's water and the *Fenton Drain*, quite up to the walls of *Torksey Bridge*; and to be made proof, so that the water shall never, after passing the weir, flow into the drain: and, furthermore, as the *Trent* floods frequently greatly over-ride the *Fossdyke* waters, even in their highest condition, it will be necessary that the water of this weir should be conveyed to *Trent* by a separate passage, intermediate between the lock and *Fenton Drain*, whose out-let must be shut by doors pointed towards the *Trent*. A proper capacity for this passage will be about 8 feet wide, and 5 feet high in the clear; but its threshold need not be laid so low as that of *Fenton Drain* by a foot, so that as the foundations may be completely in the dry, it will not be so expensive as sluice-work often turns out to be.

15th. The living waters of the *Till* can evidently have no other out-fall than into the *Fossdyke*. The *Fossdyke* will be, by the proposed mode of supplying it with water from the *Witbam*, held about 10 inches higher in very dry seasons than it formerly was; but if the *Till*, which has now little or no banks, was imbanked 10 inches, it would at all times be as competent to hold in the living waters as now, before the adjacent meadows were overflowed. But let us suppose it imbanked 2 feet, yet as the ground is low on both sides, but the lowest in *Saxelby Meadow* near *Haddow Bridge*, which then would not be more than 2 inches above that advanced height of the surface of the *Fossdyke*, this would necessarily be too small an elevation of surface for these grounds ever to have a competent drainage; but as they are but of small extent, when the living waters of the *Till* are so imbanked from them, a very small tunnel, with a competent fall, would effectually drain them; for this purpose I would propose to drain them by means of a leaden pipe of 5 inches bore, under the *Fossdyke*, into the drain proposed to be carried on the south side to *Saxelby Pasture*, laying also a small common tunnel under the *Till* to communicate a few acres of drainage from *Haddow Meadows* (which are the higher) into *Saxelby*. I prefer, in this case, a leaden pipe, because it may be lowered into the water, and completed, without ever interfering with the navigation at all. Or, if better approved, these meadows near *Haddow Bridge* may drain by a communication across the *Till* as aforesaid, (but from *Saxelby* into *Haddow*) and then by way of *South Carlton* to the great iron tunnel proposed in Article 8.

OPERATION of the preceding scheme.

UPON my late view I found the pen of *Lincoln Lock* to be good $14\frac{1}{2}$ inches, with a competent fall for the current waters of the *Witham* through *Lincoln* and the *Slaker* drains, which I estimate at $1\frac{1}{2}$ inch more, that is in the whole good 16 inches; it is therefore manifest, that by the means proposed these 16 inches will be added to the natural fall of the drainage-waters that they now have into *Brayford Meer*; and the living waters of the *Witham* will then get discharged as they do now, and the internal drains being carried upon dead level bottoms, and dug below level till they get to the pinch of their respective services, they will perform their drainage down to the dead level of their out-fall, in which case the point in *Scuth Carlton*, that is reported to have had but 1 foot $2\frac{1}{4}$ inches elevation above *Brayford Head*, as it was in 1762, that is, but $8\frac{1}{4}$ above the level of *Brayford Meer*, as I found it the 31st of August last, will then have a fall of 2 feet $\frac{1}{4}$ inch from the said surface to its out-fall; and the low flade in the west of *Skellingthorpe*, that was the same day 6 inches above *Fossdyke*, (that is above *Brayford Meer*) will have a fall of 1 foot $10\frac{1}{2}$ inches to its out-fall, which will fully suffice for a perfect drainage in seasons moderately dry; but this being somewhat less than what has been esteemed compleat, I must beg leave in this place to take notice, that formerly, when it was not the practice to dig drains below the dead level of the out-fall, nor to carry their bottoms upon a dead level, but rising towards the country to be drained, it was then held necessary to have a calculation that the utmost reduction of the water within soil should not be less than 2 feet. But the experience of the last 20 years has informed me, that where measures are taken to make the drains readily and speedily, (after the top waters are discharged) reduce their water's surface *one foot* within soil where it is tolerably firm, will form a very effectual drainage, and in soils less firm 18 inches done speedily will be full as effectual as an ultimate of 2 feet performed in that slow lingering manner which is the consequence of shallow drains, containing no competent body of water in the bottom, to be moved; for let the body be however great, gravity acting with equal force on every particle, the fall being the same, will give every particle an equal velocity, and consequently the whole. Now, as I found *Saxelby Meadow* was elevated above *Fossdyke* 11 inches, it will, by what is proposed, be elevated 2 feet 3 inches above its out-fall, and therefore several inches to spare to give its water a competent velocity through the pipe.

Hence it is evident, that the drainage of all the low grounds will be compleated in all summer seasons, but will, as at present, be subject to be overflowed by the great winter's floods, but whose top waters will be more speedily run off by the discharge into

into *Trent*, and by the drainage waters running off with a good current, when at present they do not run at all.

By avoiding all imbankments of the *Witbam*, and the waters allowed to spread as at present, all oppression of the drainage lands east of *Lincoln* is avoided; and in running off their ultimate drainage waters of the west country more speedily, the east country will be greatly benefited, because they will be sooner ridded of their western waters coming upon them; for this must be laid down as a rule, that in like circumstances, the lands downward upon a stream can never expect to drain prior to those above them, and therefore the sooner the waters of those above are discharged, the sooner the drainage of the whole will be completed.

The navigation east of *Lincoln High Bridge* will be greatly benefited, because *Brayford Head* being cleared away down to the level of the floor of *Lincoln High Bridge*, will give 1 foot more water than at present, and the like advantage would take place quite through *Lincoln*, if the *Witbam*, east of the said bridge, was suitably cleared.

The *Boston* out-fall will also receive benefit, notwithstanding that some of the top waters will be discharged into the *Trent*, because it can be no advantage to a country already oppressed with water to receive an addition; and as the follow of the living waters will be continued in a more full body after the extreams are gone, the powers of scouring will be continued to a period, when otherwise they would have ceased.

In order to state the advantage to the *Fossdyke* navigation, and its relation to the drainage of the country, it will be necessary to ascertain some fixed points of level.

In the year 1762 it was ascertained by Mr. GRUNDY and myself, that when there was $4\frac{3}{4}$ inches depth of water over *Brayford Head*, the surface was then $5\frac{1}{4}$ below the top of the *Aisler* course of the *Lincoln* stone in the face of Mr. *Ellison's* wharf, consequently the said course was at that time 10 inches above the natural staunch of *Brayford Head*.

On reviewing the same in the year 1782, I found 1 foot water upon *Brayford Head*, (as held up by the staunch of *Lincoln Lock* below) and at that time its surface was 4 inches below the said *Aisler* course, consequently the *Aisler* course 16 inches above *Brayford Head*, as it now is; that is, *Brayford Head* in 1782 was lower by 6 inches than in the year 1762, and the surface of the water of *Brayford Meer* was $1\frac{1}{4}$ higher. I would therefore recommend that the crown of the proposed weir to pen the water in *Fossdyke*, and

over which the surplusage shall fall into *Brayford Meer*, to be 5 inches higher than the said *Aisler* course, which in fact will be all that will be gained to the *Fossdyke*; because it is said, and I suppose may be proved by evidence, that when this wharf was built about 40 years ago, the said *Aisler* course was completely covered with water, that stone being of the reputed quality not to bear the weather. The crown of this over-fall being about 11 inches lower than the proposed weir at *Torksey*, will therefore be the gauge height of the *Fossdyke* navigation, whenever the flood waters do not raise the whole country above that level; and whenever that is the case, it will be proper to open the gates of the new proposed lock joining *Brayford Meer*, to let the flood waters of the *Till* have a free vend, so as not to be unnecessarily accumulated upon these lands, that necessarily drain into the *Fossdyke*.

I come now to prove lastly, that the whole of those lands, that necessarily drain into *Fossdyke*, will be benefited by the alterations proposed; because, as those all lay westward of *Saxelby*, the discharge by the weir at *Torksey* will have the greatest and quickest effect upon them in running off their top waters the most speedily; and respecting their ultimate drainage, it is manifest, that whenever the waters of the whole country is above the proposed gauge height of *Fossdyke*, that it will be the same thing to them, whether the over-fall at *Brayford* is in being or not; if, therefore, when at or under that height, all these lands have all the ultimate drainage they have now, or can have, they can be no losers in that article.

The only drain into *Fossdyke*, that has the appearance of being in the least likely to be affected by the proposed advancement of the surface of the *Fossdyke*, is *Thorney Drain*; I mean that with a pair of doors at *Drinsay Nook*. Of the circumstances of this drain I took particular notice, and must infer, that in point of ultimate drainage it fully does its business; because if it did not, as I found the water of *Fossdyke* just covering the threshold, and a rise of the pavement or floor, from the threshold of the door towards the land, of between 9 and 10 inches, I conclude, if this drain did not, in its present circumstances, do its duty, this rise in the pavement, which operates as a dam, being taken away, and the bottom of the drain lowered correspondent thereto, it would be enabled to have run off the water lower by all this difference. I took a very careful level between the surface of the water of *Fossdyke* as it then was, and the top of this stone pavement, and found that the rise was $9\frac{1}{4}$ inches in the compass of 3 yards. The water being then 4 inches below the *Aisler* course at Mr. *Ellison's* wharf, if raised 5 inches above it, this would make 9 inches; that is, the surface of *Fossdyke* would be still a quarter of an inch below the paving, and if even with the top would
be

be no impediment to any water flowing over it, for water could not flow over it without having some thickness, or depth upon it; and if it was 2 inches deep, it would have an immediate fall of 2 inches into *Fossdyke*, by which it would be delivered as fully, freely, and uninterruptedly, as if it had a pit to fall into from the top of the pavement, of 100 yards deep; and in fact, as the drain's bottom (which I pursued about half a mile) seemed to lay nearly on a level with the top of the paved floor above mentioned, and was greatly trod and poached by the feet of cattle that made their passage along it, to eat the grass upon its sides, the condition of it is such, that if the *Fossdyke*, instead of being raised 9 inches above the level it then had, was raised 15 inches, I would engage, if necessary, to make it run off its water lower at half a mile distance after that, by digging it as deep as the threshold of the sluice, than it can do at its present depth and condition, though the *Fossdyke* was totally emptied of water. It will therefore clearly appear, that the difference of an inch or two that may occasionally be made by the thickness of the sheet of water going over the over-fall at *Brayford* (or even if it was 6) will make no sensible difference in the effect of the operation of this drain, to which the more quick running off the top waters being the only thing desirable.

Austhorpe, December 31, 1782.

J. SMEATON.

PROBABLE ESTIMATES of the expence of the above works.

1st. For such works of drainage as would be necessary in case the *Fossdyke* navigation was to remain in its present state.

	£.	s.	d.
To removing <i>Lincoln Lock</i> and <i>Staunch</i> above <i>Sincil Dyke</i> , deepening the channel where necessary up to the same, and making good the wharfs, say	200	0	0
To scouring out and deepening <i>Sincil Dyke</i> from its tail to the tail of the <i>Great Gowt Drain</i> , and from thence the <i>Great Gowt Drain</i> to the <i>Witham</i> ,	172	0	0
The contingency of under-pinning the two bridges upon the <i>Great Gowt</i> ,	20	0	0
To making the subterraneous tunnel under the <i>Witham</i> ,	150	0	0
To scouring out the <i>Lesser Gowt Drain</i> , and remainder of the <i>Sincil Dyke</i> to the <i>Witham</i> ,	33	0	0
To weirs at the head of each,	30	0	0
To the drain leading from the subterraneous tunnel to the point of departure of the two drains, according to Article 7th, being 400 roods, at 9s. 6d.	190	0	0
To three lengths of iron pipes, 3 feet diameter, for the great subterraneous tunnel crossing <i>Fossdyke</i> , weight 5 tons 15 cwt. at 16l.	92	0	0
To bolts, jointing and laying,	10	0	0
To brickwork at the two ends,	20	0	0
To taking off the water and pumping,	25	0	0

Carried over £. 942 0 0

	Brought over	£.	s.	d.
To continuing the drain from the said point of departure in <i>Skellingthorpe</i> , through the iron tunnel to <i>Bishop's Bridge</i> , being 332 rods, at 8 <i>s.</i>	- - - - -	133	0	0
To rebuilding <i>Bishop's Bridge</i> ,	- - - - -	10	0	0
To continuing the drain from the said point into <i>Skellingthorpe</i> , upon a 9 feet bottom, to the point K, being 410 rods, at 8 <i>s.</i>	- - - - -	164	0	0
To continuing the said drain from the point K to the west boundary of <i>Skellingthorpe</i> , 333 rods, at 6 <i>s.</i>	- - - - -	100	0	0
		£. 1349	0	0
To 10 per cent. contingencies upon the above articles,	- - - - -	135	0	0
		£. 1484	0	0

N. B. As I suppose the trustees of the *Boston* navigation must be considered as aggressors, the removal of the lock and staunch should be at their expence.

ESTIMATE of such works as will be necessary for the improvement of the *Fossdyke* navigation upon the plan proposed.

	£.	s.	d.
To building a new lock between <i>Fossdyke</i> and <i>Brayford Meer</i> , digging and pumping	500	0	0
To additional work at the <i>Wisbam</i> tunnel, to make it serve as an aqueduct bridge over the drain, and to receive a gate for regulating the water,	120	0	0
To cutting the aqueduct from the said tunnel to the <i>Fossdyke</i> , for carrying the water for navigation, being 240 rods, and securely banking the same, at 12 <i>s.</i>	144	0	0
To two communication bridges over the same, if of brick, 20 <i>l.</i> each,	40	0	0
To making an over-fall from <i>Fossdyke</i> into <i>Brayford Meer</i> of brick or stone,	100	0	0
To making a staunch at <i>Brayford Head</i> ,	150	0	0
To deepening and scouring from <i>Brayford Meer</i> to <i>Lincoln High Bridge</i> ,	25	0	0
	1079	0	0

The following works I look upon as contingent upon the rise of the water in *Fossdyke*.

To carrying forward a drain for the west bounder of <i>Skellingthorpe</i> through the corner of <i>Saxelby Pasture</i> , and by a leaden pipe across into <i>Saxelby</i> and <i>Hadden Meadows</i> , length 256 rods, at 5 <i>s.</i>	64	0	0
The leaden pipe 12 cwt. at 1 <i>l.</i> 1 <i>s.</i>	13	0	0
Carried over	£. 77	0	0

	£.	s.	d.
Brought over	77	0	0
To solder, labour, laying, and fixing,	5	0	0
To brickwork at each end, with proper grates to shut and hinder it from choaking and running at improper times,	10	0	0
To banking upon the <i>Till</i> up to its division, length 88 rods on each side, at 2 s. 6 d. per rod,	22	0	0
To a tunnel across the <i>Till</i> , wood and laying,	2	0	0
	116	0	0
	£. 1195	0	0
To 10 per cent. contingencies upon the above articles,	120	0	0
	£. 1315	0	0

The making the weir at *Torksey*, being advantageous not only to all the lands in question, but to the navigation, by more readily freeing the same from extreams of water, and also by quieting the apprehensions that the land-owners might entertain from the rise of the surface of *Fossdyke* in dry seasons, it seems to me should be done at a joint expence.

To making the weir, walling, paving, and securing the channel for carrying off the water, imbanking between the said channel and <i>Fenton Drain</i> , making the tunnel through the road, and pointing doors towards the <i>Trent</i> , cannot lay at less than	-	-	500	0	0
Contingencies upon it at 10 per cent.	-	-	50	0	0
			£. 550	0	0

A B S T R A C T.

	£.	s.	d.
General drainage scheme,	-	1484	0 0
<i>Fossdyke</i> navigation,	-	1315	0 0
<i>Torksey Weir</i> and accompanymnts,	-	550	0 0
Total	£. 3349	0	0

Austhorpe, December 31, 1782.

J. SMEATON.

HOLDERNESS LEVELS.

REPORT of JOHN SMEATON, annexed to a Report and Estimate of Mr. GRUNDY's, concerning the Drainage of *Holderness Levels*.

HAVING carefully perused the foregoing observations, and also compared them with my own taken upon the place in the month of November last, and finding no difference between them that can any ways affect the practicability of the proposed drainage, or the general scheme to be made use of for that purpose; and having also considered the causes assigned by Mr. GRUNDY for the drowning of this level, and the expedients to be made use for the remedy of the same, I entirely concur with him in every essential point. But as a number of adverse accidents have prevented us from meeting upon this business, according to the desire of the proprietors, which has prevented our comparing our ideas together; and as mens ideas often vary in particulars though they agree in general and material points; and as I find that some things have struck me in somewhat a different light to what they have done Mr. GRUNDY, I think it my duty to point out the same, not so much by way of correction of what he has proposed, as by way of supplement.

1st. In regard to the out-fall clough, *Marfleet* must strike every one, at first sight, as being the most eligible place; and, was there any want of fall, would certainly be so; but as there appears an ample sufficiency of fall into the river *Hull* at the *Sugar-House* clough, it's being so much above low water in the river *Humber*, allows it to run so much the longer; and if laid nearer low water mark (without which it could have no preference upon the *Humber*) it would be more difficult to maintain a channel from the clough to low water mark; and the shore being flat and muddy, and the water ebbing out a great way, the sea-doors would be more liable to be filted up in dry seasons. I can therefore hardly tell how to give the preference to *Marfleet*.

2dly. Was the eastern main drain, instead of going round by *Gold Dyke Stock*, to be conducted from *Old Williams* at *b*, through *Fordyke*, to about the midway between *Fordyke Bridge* and *Fossam Style*; and there making an obtuse angle, to meet the eastern drain, about the point *VJ*. and then to proceed together in a right line to *D*, the course of the main drain would be shortened near upon a mile, which, according to the laws of drainage, is eligible, in case other circumstances of greater weight do not counteract; and then the course of the drainage of *Sutton Carr*, &c, which would be north, would be more natural; for, according to my information, those carrs are deeper about the fillings,

fillings, and *Chester Hole*, than near *Gold Dyke Stock*. The lands on the south of *Gold Dyke Stock* could drain as at present.

3dly. In case any objection is raised by the proprietor of *Wagben*, now under drainage by engines (which if this scheme takes place will be unnecessary) the eastern drain may be brought from the angle between *K* and *L*, in *Weel Carr*, through the main drain, under *Mieux Bridge*; and turning S. E. near *Lamber Coat Bridge*, to fall into the eastern drain, in a proper direction, between *b* and *c*; and though this course would be near two miles longer than the eastern one already marked out, and therefore less eligible, yet as there is fall enough, I propose it as a practicable scheme in case of difficulties.

4thly. I apprehend a sluice of less dimensions than 24 feet water-way, would drain these levels, when the banks against the river *Hull* are made tight and firm; as it seems to me that country clew would be almost sufficient, was it placed where there was a proper fall: however, I would advise nothing less than two fathoms of 18 or 20 feet, but dimensions, in this case, if an error, is one on the right side.

5thly. The places of the present cloughs are very proper for tunnels for taking in water from the river in dry seasons; but, as I cannot suppose, after the above works are executed, that they will ever run, I cannot think them worth maintaining in their present form. The present extraordinary inundation, I suppose, to be principally owing to the badness of the banks against the river *Hull*, which allow a considerable part of it's contents to be discharged upon this level.

6thly. In regard to the estimates, the shortness of the time that accidents have allowed me for these remarks, puts it out of my power to enter into them particularly; but well knowing Mr. GRUNDY's correctness and assiduity in those matters, I have only to observe, that, though I think he has allowed a sufficiency of dimensions, I should be glad he would reconsider whether the price allowed for the spade-work will be sufficient also. On this account, I would count the sum of £ 10652, exclusive of the articles of surveying, planning, schemes, estimates, supervising and other contingencies, and procuring the act.

Ausborpe, 12th January, 1764.

J. SMEATON.

EXAMINATION of Mr. GRUNDY's plan for a sea sluice for the drainage of *Holdernefs Levels*, by JOHN SMEATON.

THE general design and idea of this sluice I much approve; but as I think it may be made stronger with the same expence, I therefore submit the following remarks to Mr. GRUNDY's consideration.

1st. The sluice pit is directed to be dug 3 feet below low water mark, and the floor to be laid 1 foot below ditto.

	Ft.	In.
Thicknefs of the mud fells - - - - -	1	0
The ground fells being let down thereon, I suppose 2 inches, will rise	0	10
Thicknefs of the plank - - - - -	0	3
The pointings being let into the floor, I suppose 1 inch, rises - - -	1	1
Total rise above mud fells pile heads, - - - - -	3	2

Quere, Does Mr. GRUNDY propose letting the mud fells into the bottom 14 inches? if so, it should be more clearly expressed; as I suppose it is the second floor, or top of the threshold, that is to be 1 foot under low water.

2dly. It is proposed to pile the mud fells at every 6 feet, so that every other ground fell will bear hollow upon the mud fell, which I suppose is intended for it's principal bearing; and every ground fell, being piled in the intermediate spaces, will have a superior bearing to that where the walls stand; I would, therefore, propose to pile the mud fells under the interfection of every ground fell, and omit the intermediate piles, or do them only with slabs spiked against the ground fells, after laid; but this, in my opinion, is unnecessary; but I would add piles under every ground fell answerable to the faces of the pier, for the length of the part that at present bears hollow, and on one row of piles, at 6 feet distances only; this middle row under the pier, for the arches length, I would still continue at 6 feet distances. In this way, mud fells of 12 x 6 will do as well as 12 x 12, and the timber saved may, if thought necessary, be employed in slab piling the intermediate spaces.

3dly. The projection of the floor beyond the walls, I think not only an useless expence, but prejudicial in effect, because the back side of the wall bears hollow, and not immediately upon the pile heads; 'tis true, a wall of this sort is not inclined to fall

fall backwards, but if the ground should prove bad, and the wall be inclined to settle, (for which cause only piles seem necessary behind the front) they had better be applied directly underneath; and if the two outside mud sells, answerable to the back of the walls, are piled at 6 feet distances only, I think it sufficient.

4thly. The row of dovetailed piles under the points of the projection of the pier, I think may be safely omitted, unless the ground is very bad indeed.

5thly. If 9 inch spikes are intended for the 5 inch plank piling, they will reach only 4 inches into the wood; I have, therefore, supposed them, in the estimate, to be of 11 inches.

6thly. Out of the timber supposed to be saved as above, I would lay an additional ground sell close to the other, directly under the points of the pointings, that the jagged bolts may there have something else besides the plank to hang by; but to discontinue them upon the mud sells in the face of the walls: the three ground sells and plank piles to be all bolted together. This last ground sell I would support by 4 piles, correspondent to those marked *ddd*.

7thly. I think 1 foot rise at the threshold very sufficient, and the second floor plank may be of two inches, or the second beams of 12×9 . The 20 inch bolts proposed for the 14 inch pointings, leaves but 6 inches to go into the wood below, of which 2 inches is plank; they should be two feet at least.

8thly. It would considerably strengthen the pointings to put a brace or stretcher of an equal height with themselves, cross the pier, according to the direction of the dovetail piles; so that the string pieces, these braces, and the head of the threshold, would all mitre together; and in like manner to fix on a piece jump against the outside heels, to reach about 6 feet into the wall, and to be bolted on with two jagged bolts, each the same as the pointings are fixed by, for which there is provision in the estimate.

9thly. If the lime rubble is mixed with a little quick lime it will swell and become quite compact, which method I have used in fillings; and the second floor I think had better be filled with solid brickwork.

10thly. The projecting pier I think had better be no longer than sufficient to fasten the studs, as the water will thereby more readily act behind, and shut the doors.

11th. In regard to the plan of the walls, I think a 5 feet base, the length of the arches in this light, unnecessary; that as the arches will ever prevent the external pressure of the earth from driving them inwards, a wall of 4 feet base and 3 feet at the springers will be sufficient; but considered as an abutment to the arches, independent of the weight of earth to be rammed behind, I think it insufficient for a height of 12 feet; in this light the base had better be 7 feet, and 3 feet at top; the contre forts will undoubtedly support the extremities of the arches, but a 15 feet hollow bearing, where there is any dependence, I think is too great in brickwork or masonry.

12th. A base of $4\frac{1}{2}$ feet for the wing walls, is certainly too little for a wall that is to rise at a mean 22 feet, without the help of land ties, or cross beams; and, as I am very averse to those expedients, I would propose to make the base of the wings, at the set-on to the body, 9 feet thick; 6 feet thick joining the returns, and 6 feet for the returns; and to make regular sets-off on the back side, so as to be every where 2 feet at top; this will reduce the walls to full as small a size as is supposed at the height of 12 feet; so that the only addition will be 1 foot 6 inches mean thickness upon 12 feet high in the wings, and 1 foot thickness to ditto height in the returns, which, with the contre forts in the wings and returns, will make about $7\frac{1}{2}$ rods of brickwork; which at 6*l.* per rod comes to 45*l.* to do it durable and lasting, whereas with land ties and beams it comes to 57*l.* 8*s.* No addition of expence in the floor will be required, or alteration, save that I would conform it to this figure; and it will be necessary to lay in, instead of common planking, ribbands or whole pieces of 6 inches thick, in the face of the wing walls, to hinder their sliding upon the floor.

13th. As the upper pointing is difficult to be supported, from the pressure of the water downwards, I have proposed in the estimate to suspend them, by iron loops and stays, to the key-stones of the arches, and plank them flat upon the top.

14th. I apprehend Mr. GRUNDY has, in the height of his doors, had a view to the passages being navigable; otherwise I think, if the doors were only 8 or 9 feet high, (which would be fully sufficient for the discharge of the waters) they would be lighter, and therefore move more readily as well as be in effect stronger.

Austhorpe, 13th December, 1764.

J. SMEATON.

P. S. It seems to me that there is not occasion to dig the sluice pit to so great a general width as 65 feet: was I to execute it I should not open the ground to take in more than the extremity of the walls at bottom, and notch in the abutments, returns, &c.

&c. in which case the main pit will not be above 50 feet bottom. I have also altered the position of the sluice pit in the general plan, in order to give it a better direction into the river, which, being in dotted lines, will readily be distinguished.

N. B. I have in the estimate supposed the walls to be carried up 12 feet high, the same thickness as ordered for the base.

ESTIMATE of Mr. GRUNDY's plan for a sea sluice for the drainage of *Holdernefs Levels*.

CARPENTRY.

In 84 piles under the mud fells, being 10 inches by 12 head, and 10 feet long, 1 piece of 12 inches	Cube Ft.
square and 10 feet long, make 2 piles; therefore the solid contents,	420
In 7 mud fells, 64 feet long, 12 by 12,	448
In 96 bearing piles, 10 by 12 head, and 10 feet long,	480

	Cube Ft.
1 Grounding to sea sheet piling, 73 feet long, 12 X 12,	73
9 Ditto in the sea apron, mean length 49 feet, 12 X 12,	441
2 Ditto under the sea doors, 62 feet long,	124
5 Ditto under the body of the sluice, 44 feet long,	220
2 Ditto under the land doors, 57 feet long,	114
4 Ditto under the land apron, 45 feet long,	180
1 Ditto to land sheet piling, 62 feet long,	62

In 24 ground ways, 12 X 12, 1214

In 2 rows of 12 feet dovetail piles under extremity of the sea aprons and sea doors, length

134 feet, there is feet superficial, 1608

In 2 rows of 10 feet ditto, length 106 feet, feet superficial, 1060

Superficial feet of dovetail piles, 2668

Allow $\frac{1}{4}$ for tonguing 334

Superficial feet, 3 inches thick, 3002

The solid contents thereof is, cubic feet, 1281

1 Row of ditto in the extremity of the land apron, 4 inches thick, and being in length

62 feet, and allowing $\frac{1}{4}$ for tonguing, make, in solid contents, 257

Timber in the 5 rows of dovetail piling, 1458

3640 Feet superficial of plank in the floor, being 3 inches thick, contains solid, 910

6 Ground

	Cube Ft.			
6 Ground sills for the second floors under the arches, mean length 21 feet, 12 X 10,				
solid contents,	106			
4 String pieces, 20 feet long, 10 X 6	36			
4 Pointings, 14 X 16, and 7 feet long each,	48			
2 Land thresholds, 14 X 16, and 15½ feet long,	49			
Plank for the second floor, 3 inches thick, 504 feet superficial, containing solid	126			
Timber in the second floor and thresholds,	361			
<i>Riga</i> timber in the floor,	Cube feet	5291		
	£.	s.	d.	
To <i>Riga</i> timber in the floor, 5291 feet solid, at 14d.	308	12	10	
Allow for waste in converting to the proper scantlings one eighth	38	11	7	
To timber in the floor,	347	4	5	
To preparing and driving 180 piles of 10 feet long, at 2s. 6d. each pile,	22	0	0	
To framing, sawing and laying the floor, containing 37 square, at 15s.	27	15	0	
To 2668 feet superficial of dovetail piling, sawing, making and driving, at 4d.	44	9	4	
To laying 37 square of planking in the floor, including sawing and caulking, at 7s. 6d.	13	17	6	
To framing and laying the second floor, containing 5½ square, at 1d. 2s. 6d.	6	3	9	
Workmanship in the floor,	114	5	7	
Timber in ditto,	347	4	5	
Carpentry in the floor,	£. 461	10	0	

Masons and Bricklayers work.

The external circumference of the walls and pier is 292 feet by 12 feet high, produces 3504 feet of face work, which will be, at a medium, 1 foot 3 inches thick of stone; this produces 4380 cube feet, which, delivered at 1s. 6d. per-foot, comes to,	328	10	0
The setting and making mortar for ditto, at 1d. per foot,	18	5	0
This being supposed to be set 6 inches breadth in tarras mortar, and the hollow posts wholly bedded therein, will take 50 bushels of tarras, at 3s. 6d.	8	15	0
To extra labour in beating the mortar made therewith, at 1s. 6d. per bushel,	3	15	0
To lime and sand for making the tarras mortar, and bedding the stone work, containing 14 rods, at 2s.	6	6	0

Masonry to 22 feet high,

To

To stone facings for the wings and returns to 6 feet above the spring of the arches,	Sup. Ft.	Solid Ft.
- - - - -	966	1208
To ditto in the 2 face walls,	1088	1360
To ditto in the 4 rampart walls,	460	565
	<hr/>	<hr/>
	2514	3133
	<hr/>	<hr/>

			£.	s.	d.
To 3133 cube feet of stone work, at 1s. 8d. per foot,	-	-	234	19	6
To setting ditto and making mortar, at 1d. per foot,	-	-	13	1	1
To lime and sand for mortar for ditto, 10 rods, at 9s. per rod,	-	-	4	10	0
			<hr/>		
Masonry above 12 feet high,	-	-	252	10	7
Masonry below 12 feet high,	-	-	365	11	0
			<hr/>		
Masonry in the face of the walls,	-	-	£. 618	2	7
			<hr/>		

Estimation of a rod of Brickwork.

			£.	s.	d.
To 4500 bricks, at 15s. per thousand,	-	-	3	7	6
To 20 bushels of <i>Houghton</i> lime, at 8d.	-	-	0	13	4
To 40 bushels of clean sand, at 3d.	-	-	0	10	0
To workmanship,	-	-	1	8	0
			<hr/>		
Rod of brickwork,	-	-	5	18	10
			<hr/>		
This, in the following estimate, I call	-	-	6	6	0
			<hr/>		

The whole contents in solid, to 12 feet high, is 13548 cube feet, from which deducting 4380, the cube measure of the masonry, there remains 9168 cube feet of brickwork, making 29.7 rods, at 6l.

178 24 0

The brick backing for the wings, and returns, to make the whole 3 feet thick at a medium,	1690 cube feet.
To ditto for the faces to make the same thickness,	1428
To ditto in the rampart walls, to make the whole, at a medium, 2 feet 3 inches thick,	420
To cube measure in the arches a brick and half	712
	<hr/>

Brickwork completed, 4250 cube feet.

The upper works in brick contain 4250 cube feet, which, at 309 feet to the rod of 14 inches thick, contains 13.8 rods, at 6l.

82 16 0

Brickwork in the backing and arches,	£. 261	10	0
	<hr/>		

Carpentry in the sea and land doors and pointings.

A sea door, - - - - -	Ft. in cube.			
In 1 turning post, 13 feet long, 9 × 9, - - - - -	7	4		
1 Clapping post, 12 feet long, 9 × 9, - - - - -	6	3		
The under rail and upper ditto, 9 × 9, - - - - -	7	11		
4 Rails, 28 feet long, 9 × 7½, - - - - -	13	3		
66 Feet of inch and ½ plank - - - - -	8	3		
Solid timber in each door, - - - - -	43	0		
To 43 feet of timber in each door, framing and hanging, at 3s. 6d. per foot, is			£.	s. d.
7l. 10s. 6d. each door, and for 4 sea doors, - - - - -			30	2 0
	Cube Ft.			
In the main beam for the pointings, 34 feet long, 12 × 14, - - - - -	40			
The 4 pointings, 28 feet long, 12 × 12, - - - - -	28			
The king pieces, 6 feet long, 12 × 12, - - - - -	6			
The covering with 3 inch plank 36 feet superficial; - - - - -	9			
To timber and framing in the pointings, at 3s. 6d. - - - - -	83			
			14	10 6
Land doors, being 11½ feet wide by 8 feet high, contain 92 feet superficial, and being 4 inches thick, - - - - -	31			
With 4 battens on each side, 2 inches thick, 1 foot broad, and 8 feet long, contain 64 feet superficial, - - - - -	11			
Solid timber in each land door, - - - - -	Feet	42		
To 42 cube feet of timber in each land door, framing and putting in place, at 3s. 6d. is 7l. 7s. each, and for 2 doors, - - - - -			14	14 0
Carpentry in the doors and pointings, - - - - -			£.	59

Carpentry in the beams and land ties.

	Cube Ft.			
To 4 land ties in each sea wing, and 2 in each return, sea and land in all 16, to be 24 feet long, 10 × 6, - - - - -	171			
To 16 cross pieces and ditto string pieces, 3 feet long, 10 × 6, - - - - -	43			
To cube feet in land ties, at 3s. - - - - -	214		32	2 0
To 32 10 feet piles, 10 × 8 head; timber, making and driving, at 6s. each, - - - - -			9	12 0
To 3 beams of Riga fir over the sea, and 1 over the land apron, mean length 33 feet, 12 × 12; 132 feet, at 14d. - - - - -			7	14 0
To 16 knee pieces for the same, at 5s. - - - - -			4	0 0
To making, getting into place, and fixing the beams, - - - - -			4	0 0
Carpentry in the beams and land ties, - - - - -			57	8 0
Ditto in the doors and pointings, - - - - -			59	6 6
Carpentry in the upper works, - - - - -			£.	116 14 6

Iron Work.

Trail sheeting 73 feet, 146 of 11 inch spikes,	-	lbs.			
		146			
Row in point of pier 47 feet, 94 of 10 inch ditto,	-				
		73			
Ditto in extremity of land apron 63 feet, 126 of 9 inch ditto,		72			
			£.	s.	d.
To spikes for the sheet piling at $3\frac{1}{2}d.$	- - - -	291 lbs.	4	4	10
To 16 bolts for bolting the 2 ground fells and sheet piles, together in the 2 rows under the sea and land doors, weighing $4\frac{1}{4}$ lbs. each, in all 76 lbs. at $6d.$	- - -		1	18	0
To 2500 8 inch spikes for the floor, weight 10 Cwt. at $1l. 10s.$ per Cwt.	- -		15	0	0
To 28 jagged bolts, 2 feet long and $1\frac{1}{2}$ inch thick, weight 10 lbs. containing 280 lbs. at $4d.$			4	13	4
To spikes for the second floor, 1 Cwt. at $1l. 10s.$	- - - -		1	10	0
			27	6	$2\frac{1}{2}$
Contingencies thereon,	- - - - -		2	13	$9\frac{1}{2}$
Iron Work in the floor,	- - - - -		£. 30	0	0
To 4 pair of L's and 8 ditto of T's for each sea door, and for the 4 doors 48 pair, weighing, with their rivets, 14 lb. per pair, in the whole 6 Cwt. at $2l. 2s.$	- -		12	12	0
To $\frac{1}{2}$ crown nails for the planking of the gates $\frac{1}{4}$ Cwt.	- - -		0	10	0
		lbs.			
To 4 9-inch hoops for the feet of turning posts, weight 10 lbs. each,		40			
To 4 8-inch hoops for tops of ditto, 9 lbs. each,	- -	36			
To 4 2-inch gudgeons for top of ditto, 20 lbs. each,	-	80			
To 4 loops or staples for fixing ditto, 28 lbs. each,	- -	112			
To hoops, loops and gudgeons, for sea gates,	- -	268 at $4\frac{1}{2}d.$	5		
		Cwt.	lbs.		
To 4 bottom gudgeons and 4 pots of cast iron,		1	0	1	0 0
To 4 screw bolts, 18 inches long, $\frac{1}{4}$ thick, weight			16		
To 4 ditto of 4 feet long for ditto, weight 7 lbs. -			28		
To bolts for the upper pointings, at $6d.$ per lb.			44	1	2 0
To 2 sets of loops and stays for hooking the upper points of the key-stone of the arch, 50 lbs. each, at $4\frac{1}{2}d.$	- - - - -			1	17 6
To spikes for the planking of the upper pointings,	- - -			0	5 0
To rivet nails for the land doors, 100 in each door, $\frac{1}{2}$ inch thick, at $3d.$ each,	-			2	10 0

For drawing the land doors.

To 2 clasps and eyes with rivets,	- - - -	lbs.			
		64			
To 2 studs with plates for fastening to the wall, 12 lbs. each,	- -	24			
To 2 chains 16 feet long, $\frac{1}{4}$ iron,	- - -	146			
To 2 studs and 2 loops for fixing ditto,	- - -	16			
Fixed iron work for drawing the land doors, at $4\frac{1}{2}d.$	- -	250	4	13	9
Vol. I.	O	Carried over,	29	10	

	Brought over,	£.	s.	d.
To a common hand-screw fitted up for drawing the gates,	- - - - -	29	10	9
To 50 cramps for the cappings, 2lbs. each, 100lbs. at 4d.	- - - - -	5	0	0
To 5 pigs of lead to fasten cramps and iron work, at 16s. each,	- - - - -	1	13	4
		4	0	0
Contingencies,	- - - - -	40	4	1
		4	15	11
Iron work in the upper works,	- - - - -	45	0	0
Ditto in the floor,	- - - - -	30	0	0
Iron work in the whole,	- - - - -	£. 75	0	0
To 188 cube yards of lime-stone rubbish, mixed with 1 bushel per yard of quick lime, well blended together, and rammed in between the timbers of the floor before it is planked,	- - - - -	28	4	0
To $\frac{1}{2}$ a rod of brickwork between the timbers of the second floor, close laid in and filled with mortar,	- - - - -	3	0	0
Filling in the floor,	- - - - -	31	4	0

A B S T R A C T.

	£.	s.	d.
Carpentry in the floor,	461	10	0
Masonry in the face of the walls,	618	1	7
Brickwork in the backing and arches,	261	10	0
Carpentry in the upper works,	116	14	6
Iron works in the whole,	75	0	0
Fillings in the floor,	31	4	0
Drainage of the water, supervisal, and contingencies,	200	0	0
	£. 1764	0	1

BRISTOL BRIDGE.

QUESTIONS proposed by Mr. STRATFORD, Engineer, concerning *Bristol Bridge*; answered by Mr. SMEATON.

Quere 1st. **F**ROM the state of the old pillars, and strata below the bed of the river, to the solid red sand rock, will it be prudent, or adviseable, to attempt the construction of a new superstructure on such old precarious foundations?

Having duly considered the several matters stated in the foregoing discourse*, as well as the several plans, elevations, and sections, I am of opinion as follows:

Answer 1st. As all the old pillars appear to be ill built and damaged, and not sufficiently deep below the bed of the river, which will always render them subject to further injuries from the action of the water, which appears here to be very considerable, I should think this sufficient to their condemnation, if the circumstances of their being ill sized, ill shaped, and ill placed, were not in the present case to be added.

Quere 2d. From the forementioned account of the freshes, will not any attempt to bar up the bed of the river under the bridge be extremely injudicious, and a measure that will greatly add to the present inconveniencies felt at the head of the back?

Answer. The bars mentioned to be thrown up, both above and below bridge, have undoubtedly been formed by the matter removed by the current from between the piers; which removal has been occasioned by the bulk of the pillars too much straightening the water-way, which, increasing the current there, has taken out the matter and increased the depth, thereby nature having in some measure relieved herself, by getting in depth what she was debarred from in width; an attempt therefore to refill those cavities will either be attended with the same consequences, and an increase of the bars, or, if the new matter to be added, is so heavy and compact as to resist the current, the current must be proportionably increased thereby. I should therefore think this expedient in this place very unadviseable.

* Meaning Mr. *Stratford's* description of the situation, condition, &c. of the old pillars, and of the several strata under the bed of the river, &c.

Quere 3d. The position of the bridge being a matter of moment in bridge building, will not the changing the present position of the old bridge be a real improvement to the part of *Bristol* at the head of the back, as it will facilitate the passage of all sorts of vessels through bridge; and may not a reasonable expence to gain that advantage be money judiciously expended for the benefit of the city of *Bristol*?

Answer. All bridges ought as near as possible to have their piers parallel to the natural current of the water, in the place where they stand; yet a small deviation therefrom, so far as it respects the passage of the water only, is not of great consequence to a work that is otherwise firm and well founded: but in the present case, with respect to the laying and passage of vessels, the deviation very unluckily happens to be the wrong way, and therefore in the reconstructing this bridge ought to be rectified. I don't mean that the piers ought to be out of parallel with the stream, but if they had happened to have deviated as much the contrary way, there probably would have been no need of a change. This ought however to be attended to, that at the same time the freshes, floods, and strong ebbs, render the vessels along side the quay less steady, it may be the means of preserving the face of the quays from an addition of silt or mud; yet the quantity of alteration proposed, cannot I think be attended with any danger from this quarter.

“ Question 4th. In case of a three-arched bridge, situated on so rapid a river as at *Bristol* Bridge, will it not be more eligible to construct the salient angles or becs of the piers with cylindric surfaces of 60 degrees, rather than an angle of 90 degrees, or rectangular?”

Answer. As the shoulder angles of the piers obstructed the water's passage, and the more so as these angles are less obtuse, in all currents they ought to be rounded off; provided this is done, it is little material what angle is formed at the bec; but no way is more advantageous than cylindric surfaces of 60 degrees, which is at present the practice of most foreign engineers.

“ Question 5th. The first design a single arched bridge, the cord at low water mark 150 feet, the plumb or perpendicular $32\frac{1}{2}$ feet, the springers of the arch to be carried down, and sunk into the solid red sand rock, according to the plan referred to; will there be any sort of danger or hazard in executing a work of this large span, under a supposition that the springers of the arches are carried down to the solid rock?”

“ N. B.

" N. B. The stone designed for the bridge is a sand stone, which rises soft in the
 " quarry, but immediately hardens in the open air to an amazing firm texture, at the
 " same time the stone can be raised in blocks of any size: I propose one sort of arch stones
 " of $6\frac{1}{2}$ feet long, and 3 feet in the sffit or thickness, and from 3 to 4 wide; the second
 " set 4 feet 3 inches long; 4 or 5 feet wide, and of the former thickness; the counter
 " arch to bond in with the principal arch, according to the section referred to. The
 " stone designed for the counter arch is excellent, being 4, 5, or 6 inches thick, very
 " wide and long.

" The lime for the mortar of the bridge is of an admirable nature; one sort will set
 " and cement under water, equal with Dutch terras; and the other will also set and
 " cement the stonework together, as if formed of one solid mass.

" This arch from the springers contains 125 degrees of a circle, consequently is 5 de-
 " grees above $\frac{3}{4}$ of a semicircle, which PALLADIO recommends in all his bridges.
 " As this arch is to be founded upon the solid rock, this arch may be looked upon as
 " semicircular, as the rock may evidently be supposed the part of the arch deficient of a
 " semicircle. A great advantage in a scheme arch, built on a solid rock, is, that the
 " less number of degrees the arch contains, the stronger the arch will be."

Answer. I look upon it that no limit to the span of arches, in proportion to their rise,
 has as yet been found, since the widest and flattest arches that have been attempted,
 upon right principles, have succeeded as well as the narrowest and highest, provided
 the abutments are good, and the stone and cement whereof they are composed are of a
 firm texture, as in the present case they are said to be: and as no abutment can be
 better than a solid rock, and since the manner of carrying down the arch, and stepping
 it thereupon according to the section, is quite proper, I see no reason to doubt of
 success, if built upon the plan now before me.

The *Aberthan* or *Watchet* lime, which I suppose is here hinted at, I look upon, from
 experience, to be the best in the world for works under water.

Question 6th. The second design I propose to consist of a large central arch, and
 two side arches. In this design will it not be most adviseable to carry down the piers
 and abutments to the solid rock.

Answer. Though I apprehend the piers of a bridge might be securely fixed upon any
 of the strata mentioned, by piling and other timber-work, provided there was no
 other

other to come at, yet as a rock is undeniable, I look upon it worthy of a considerable addition of expence to come at it in a work intended to be lasting: how far it may be practicable in the strata mentioned to get down to the rock by battardeaux, in the middle of the river, I am somewhat dubious; and though it may be come at by the caisson method, yet, as I think to interpose a grating or floor of timber between the solid rock and solid masonry, is not quite the thing to be wished for; I should therefore prefer the single arch, as having fewer foundations, and those more easy to be fenced off and come at, and should prefer the 150 feet arch to one of lesser span, as the abutments will advance less into the river.

Question 7th. The third design, proposed by Mr. BRIDGES, where the new piers are to be seated on a coping on the old pillars. But as there are so many real objections to this plan, will it not be the most judicious and adviseable step entirely to reject every proposal already offered or to be offered for executing that vague scheme.

Answer. As to Mr. BRIDGES's plan I can say nothing, as not having seen it; but if the old piers are as represented, I think it quite wrong to make use of it at all, for the reasons in the first answer. This I am sure of, if the bottom is unsound, no coping, or any thing else that can be done, can make them sound. Besides, to leave the old spreading bottoms to project under water much beyond the new shafts, and that in an irregular manner, would be very prejudicial, not only to the passage of the water, but the navigation; I therefore must conclude, that if a new superstructure must needs be built upon the old bottom, I think it most adviseable to shape the piers, and build the bridge conformable.

The queries answered by J. SMEATON.

Austhorpe, November 24, 1762.

RYE HARBOUR.

The REPORT of JOHN SMEATON upon the harbour of *Rye*, in the county of *Sussex*.

THE harbour of *Rye*, once so famous and flourishing, lays in the bottom of a bay, terminated by the point of *Dungeness* on the east, and of *Beachy Head* on the west, but more immediately by *Point Fairlee*, which lays almost in the same line, at about the distance of 5 miles. This harbour, according to tradition, was formerly very large, capacious, and deep, so that many large ships might lay therein, sheltered from all winds, at anchor at low water. In this state the sea waters every tide overflowed a very large tract of country (now converted into marshes), the influx and reflux of which waters from and to the sea produced so great a power of cleansing and opening, as to maintain itself a channel wide and deep enough for the above beneficial purposes.

Now as the whole of the waters so flowing in and out each tide must pass through the mouth of the harbour, the action thereabouts would be the strongest of all, and in proportion weak towards the remote extremities: the mud, therefore, and impurities brought in by the sea, and soil brought down by the rains from the high country, would first of all be lodged at those extremities, which gathering by degrees, in proportion lessen the capacity of the reservoir, which of consequence weakens the influx and efflux, and thereby increases the tendency to silt, or, as it is here called, to swerve up; and those surfaces so overflowed being by degrees raised out of the reach of common neap tides, begin to gather a surface of grass, which tempting the husbandman to enclose with banks, he thereby shuts out the sea totally, and in consequence weakens the cleansing power more suddenly than would happen in a state of nature; so that in time the whole of such an inlet will be silted or swerved up, unless a sufficient quantity of land or flood waters have their passage through the same to sea; and the channel remaining at last will be in proportion to the quantity and rapidity of these flood waters. This is the natural tendency of every creek or harbour upon the sea, but differing greatly in degree as situations and quantity of fresh waters from the land, and the impurity of the land or sea water, differ in one place from another.

It appears further, that an immense quantity of flint, pebbles, or broken flints, rounded by the action of the sea, commonly called stringle or beach, and which have
either:

either proceeded from the chalk cliffs on the coast, or have been washed up from the bottom of the sea, are produced to the westward of this harbour, and being driven on the shore, which runs in a general direction nearly W. S. W. and E. N. E. the wind at any point between S. and S. W. causes the seas to strike the shore in an oblique direction, and not only to heap up the beach upon the coast, but to drive it along the shore to E. N. E. into the bottom of the bay; that is, into the mouth of the harbour, from whence there is no possibility of return by a contrary action, because all winds from E. to S. E. which should produce that effect, are in a great measure land-locked, and not only so, but are generally less continued and violent than the South-Westerly. Hence then it appears, that two powers of nature are together combined to produce the destruction of this harbour, viz. the filling within, and the action of the winds and seas without, upon the shingle, to block up its mouth; nor could this last be possibly avoided, in a very little time, was it not for the action of the land waters, which will always maintain themselves a passage to sea, (while they have no other) and though considerable in the winter season, are yet very inadequate to the keeping open such an arm of the sea as this has formerly been, or even now is. The quantity of beach or shingle that has thus gathered at the bottom of this bay and mouth of the old harbour makes a surface of several hundred acres, the position of which in some measure appears by the plan hereto annexed, and is at present in an increasing state; for, as I am informed, that which at present is called the outermost west point has been formed within these ten years; and that which is now called the innermost was then called the outermost; and the point marked B in the plan was then called the innermost, which is conformable to a plan made in the year 1738. Hence it appears, that a succession of points have formed themselves to the westward of the harbour's mouth, every one leaving a more narrow passage than the former, the present opening between the present points not being above 100 yards wide. There also appears to be a body of beach, marked in the plan A, which is driving down from the westward, in all probability, and will form a point without the present, leaving a passage still narrower. From this view it appears, that the old harbour has been subject to great mutation, and is likely to be subject to still more, and all for the worse; and all able artists, who have surveyed the same, have agreed, that nothing to purpose can be done towards restoring the old harbour, or maintaining the same in any tolerable state. In this condition it appeared upon a survey in 1698, by two Commissioners of the Navy and two Elder Brethren of the Trinity House, by order of the Right Hon. the Lords of the Admiralty, who conclude their Report with saying, "And therefore we take this harbour to be almost entirely lost, at least in no condition to be preserved for any purpose of the navigation." Indeed, three gentlemen, who were sent to survey the harbour of Rye, by order of the same board, in the year 1719, after declaring their

insensibility

sensibility of the former utility of this harbour, and the bad condition it was then in, propose a remedy; but as this appears quite inadequate to the object, since that time a new harbour was projected, and in part executed, by the famous Captain PERRY, who, after performing several great works in *Russia*, and effectually stopping the breach in the river *Thames* at *Dagenham*, was employed here; and this new harbour has been carried on, with some interruption, from that time to this. Its general design and situation is as follows:

The mouth of the new harbour is situated about two miles to the westward of the old one, where the coast makes nearly a straight line for several miles together, and though altogether formed with beach, yet seems to have had no considerable increase of late years, at least not since this harbour was begun; for though a succession of shingle is moving to the eastward, it does not stay here, but lodges in the bottom of the bay. The coast being hereabout W. S. W. and E. N. E. as before mentioned, the mouth of the harbour points nearly square thereto, that is, to S. S. E. or rather S. E. by S. At the foot of the beach, which is about low water mark at neap tides, begins a fine firm sand, regularly inclined towards low water, which at spring tides is about 257 yards from the foot of the beach, and from thence inclines by very regular and gradual soundings, so as to make 20 feet water at low water spring tides, and about 23 feet at ditto neap tides, at above a mile right out from the harbour's mouth, which soundings gradually increase further out, and the whole of the bay is excellent anchoring ground, as I am informed. The tides here, at a common spring tide, rise above low water mark 23 feet, and neap tides about 14, that is about 17 feet above low water mark spring tides, which are the greatest tides I have met with on this coast. The direction of the tides is nearly along shore, and being some distance (on account of the depth of the bay) from the main channel tide, are very gentle, and are attended with this particular circumstance, that whereas the main channel tide sets to the eastward for some time (in most places three hours) after high water, which occasions a strong current to the eastward, at the time of high water; now in the bottom of this bay, the time of still water, and that of high water, are both nearly the same, which is a great advantage to ships steering into the harbour's mouth, especially in bad weather; all which circumstances, viz. the great rise of tides, the easiness of the current, and stillness at high water, when vessels chiefly go in and out, must be allowed to be advantages favourable to the construction of an harbour in this place.

With respect to the harbour itself, in its original design, it had two stone pier heads projected into the sea, as far as the foot of the beach, their distance 120 feet, which makes the opening of the harbour's mouth; but as the course of the beach was inter-

cepted by the west head, and in consequence a body of it collected behind the said head, the west head has lately been advanced further out with timber and stone, so as to overlay the east pier 210 feet, which addition is not only the means of preventing the beach from getting round the head so easily as before, but greatly facilitates the entry of the harbour, especially in the time of heavy seas from the S. W. as I have had an opportunity of being eye-witness of a vessel coming in for shelter under these circumstances.

From the pier head the width of the harbour enlarges to about 200 feet wide, and is altogether in the form of a canal, which, in my opinion, is preferable to any other for an artificial harbour, on account of the advantages in scouring, where the whole depends thereon.

At the distance of 730 yards, or thereabouts, within the piers, is placed a large navigable stone sluice, and the whole of the canal between the pier heads and the sluice is formed into the arch of a circle of about 45 degrees; so that no part of the mouth of the harbour can be seen from the sluice, nor any part of the sluice from the mouth of the harbour; in consequence whereof, not only the destruction of the sluice-gates by the sea's rolling in upon them, are prevented, but a space of above 200 yards of the canal, from the sluice downwards, becomes still water, in time of the greatest seas, at the harbour's mouth, which is particularly convenient for such vessels as come in for shelter, and only wait to take the advantage of better weather, or a favourable wind. At present the bottom of the channel between the pier heads is about 6 feet above low water mark at spring tides, and about 3 feet above the cill of the sluice: so that at present there is 17 feet water between the heads at spring tides, and 11 feet at neap tides; but as the body of beach that served as a dam in the harbour's mouth, to prevent the sea from coming in till the works within were completed, has never been totally removed, and as in its present state a sufficient body of back water cannot be collected for effectually cleansing and keeping open the mouth of the harbour, it cannot be looked upon at present as having the greatest depth of water of which it is capable. I am therefore of opinion, when these requisites are provided for by completing the whole scheme, that then the mouth of the harbour, as well as the internal part up to the sluice, may be kept clear, at least as low as the level of the cill of the gates, in which case the common spring tides will give 20 feet water into the harbour and through the sluice, and neap tides 14 feet; which latter I apprehend to be sufficient for common built merchants vessels of 300 tons burthen,

The sluice is built of *Portland* stone, and consists of two openings, one of 40 feet, shut by folding gates pointed to landward, the other of 30 feet clear water-way, shut by five draw-gates of 6 feet wide each: the use of these gates is to shut in the tides received into the canal above the sluice on tide of flood, into which vessels may then pass, or at high water through the great opening, or repass at high water or on tide of ebb; and gates being afterwards shut, and thereby a body of water penned into the canal above the sluice, serves either to keep vessels therein afloat during the whole time of tide, or being let off at low water by means of the draw-gates, produces a scour for keeping open the harbour below.

The length of the canal above the sluice is half a mile very nearly, and at a medium is about 150 feet wide at the water's surface, 70 feet at bottom, and dug down to the level of the cill of the sluice. This canal alone, exclusive of the outer harbour, will take in above 200 sail of vessels, but yet does not contain a sufficient body of water to produce the necessary scours below; and furthermore, this part of the canal being liable to fill up by the deposition of mud brought in by the sea, will in a few years be choaked up, and rendered entirely useless; the silt being gathered at least 4 feet deep at the head of the canal since July last, when the harbour was opened; what therefore is principally wanting to compleat what I apprehend to be the original scheme, is to bring the land waters and freshes of three rivers, that now discharge themselves into the old harbour of *Rye*, through the new harbour, by which means the whole will be kept clear, as appears to me for the following reasons:

The river *Rother*, together with the *Breade* and *Tillingham* channels, which unite in the old harbour of *Rye*, are said to receive the downfall and spring waters of above an hundred thousand acres of land; the discharge from whence in rainy seasons must be very considerable. But without entering into a minute disquisition concerning the quantity of surface, the most certain way of judging appears to me from observation of the size and sort of channel that those rivers respectively are enabled to maintain, so far up as where the silt, brought in by the sea on one hand, and driven out by the land waters on the other, is already come to a balance; and such I take to be the channel of the *Rother* immediately below *Scotch Flat Sluice*; the *Breade* or *Winchelsea* channel below *Winchelsea Sluice*; and the *Tillingham* channel about a mile above the *New Bridge* at *Rye*. Now it appears to me, that the *Rother* and *Tillingham* waters united are sufficient to maintain a channel, from the new canal to the town of *Rye*, capable of carrying up vessels of 300 tons; that the *Breade* channel is capable of maintaining a channel sufficient for ships of 100 tons to *Winchelsea Sluice*; and that the three together are capable of preserving an

open channel through the present canal and new harbour, so as to make at least 14 feet water at neap tides, as abovementioned ; and that the necessary widening these channels, for the purpose of discharge of land waters and navigation, will also furnish a sufficiency of reservoir for taking in the tide for the purpose of scours in dry seasons, when those rivers do not afford a sufficiency of water for that purpose ; and as this part of the scheme is still to execute, I would recommend it to be done upon the following general principles :

1st, then, I am of opinion, that the present clear water-way at the sluice of 70 feet is sufficient for taking in as much tide-water as is necessary for the purpose of scouring the outward harbour, and for filling a channel sufficient for navigation to the towns of *Rye* and *Winchelsea*, and for bringing down and discharging the land waters.

2d. I am of opinion, that a greater capacity than is necessary for the purposes abovementioned is hurtful, as a channel too wide will be maintained from filting with greater difficulty ; and the taking in too great a body of water will bring in a greater quantity of silt, and will occasion an unnecessary fall of water at the sluice, too great for the quiet passage of vessels ; and that the tide falling without, before the internal parts are full to the same level, will occasion a diminution of depth of water for the vessels from the sluice upwards. I would therefore propose, that the channel of *Winchelsea*, from the upper end of the new canal to the town of *Rye*, be widened, deepened, and straightened, so as to be 50 feet wide in the bottom ; each side to batter at the rate of 2 feet horizontal to 1 foot in depth ; the bottom to be so disposed, as to make a part of a plane regularly inclined from the lower end of *Scotch Flat Sluice* upon the *Rother*, to the cill of the great sluice : in which case, as the low cill of *Scotch Flat* lays about $5\frac{1}{2}$ feet higher than the cill of the great sluice, the bottom of the new channel joining upon the new canal at C will be 7 inches higher, and the other end of the new channel D at *Rye* will be 2 feet 10 inches higher than the cill of the great sluice at the point D ; the banks or walls of this canal to be set at least 40 feet from the brink thereof, and to be raised to 25 feet above the cill of the great sluice, to be 6 feet top, to batter 3 to 1 towards the canal, and 1 to 1 landwards.

3d. From the point D to make a cut to the north of the town of *Rye*, to fall into the river *Rother* at some convenient point, suppose E ; this cut to be 40 feet bottom, to agree with the inclined plane aforesaid, its sides to have the same batters as the former, and its banks or walls to be raised to the same height, to have the same dimensions at top, the same batters and distance as before described, as far as the crossing of the turnpike-road F.

4th. To

4th. To fix a dam across the river *Rotber*, near below the point of diversion E, and to erect a sea wall from the said dam, to some convenient point eastward, upon the present sea wall of the marsh G, and to carry another sea wall from the said dam westward, to abut upon the turnpike road at F, which dam and walls are to be raised to an equal height with the adjoining wall against the marsh, to be 6 feet at top, and to batter both ways, as $2\frac{1}{2}$ to 1.

5th. As a bridge will be wanted upon the turnpike road, before mentioned at F, for crossing the canal, I would propose it to consist of 3 arches, one of 13 feet 6 inches wide, the others of 12 feet each; the large opening to be furnished with two pair of folding gates, pointed to seaward, and 1 pair of ditto pointed to landward; the cills of these gates to be laid even with the proposed bottom of the canal at this place, that is, about 2 feet 10 inches above the cill of the great sluice, and about 1 foot 8 inches below the lower cill, and 2 feet 11 inches below the cills of the navigable chamber of *Scotch Flat Sluice*.

6th. A navigable sluice to be fixed across the *Tillingham* channel, at some convenient place within half a mile above the bridge at the ferry, suppose at H, of 13 feet 6 inches in the clear, with a pair of gates pointing to seaward, and ditto to landward, with draw shuttles or flakers in the latter, and the walls or banks of the *Tillingham* channel, from the said sluice downwards, to its junction with the canal before described, to be heightened in such manner, and in such proportion, as is described for the main channel from the new canal to *Rye*.

7th. A dam to be fixed across the present combined channel of *Winchelsea* and *Tillingham*, at or near the present new bridge at *Rye*, suppose at K, and the road to be carried over the said dam; the top thereof to be made up to the same height as proposed for the aforesaid new channel from the canal to *Rye*.

8th. The channel of *Winchelsea*, from the new canal to *Winchelsea Sluice*, for the purpose of navigation, and also to obtain a sufficient quantity of earth for the necessary strengthening of its walls, to be widened and deepened at the head of the new canal, to 2 feet above the floor of the great sluice, and to be carried upon an inclined plane, so as to agree with the cill of *Winchelsea Sluice* at that place; the batters of its sides, the height, strength and batters of its walls, to be the same as proposed for the main channel from the new canal to *Rye*.

9th. That

9th. That in case the diversion of the land waters shall occasion the out-fall of *Wenway Sluice* to choak up, then a new channel to be cut, and sluices erected, for the discharge of *Wenway's* waters, above the proposed dam at E, into the *Rother*.

10th. That in case of the total choaking up of the old harbour's mouth, upon the diversion of the rivers into the new harbour, as is to be expected, then the proprietors of such ground as is to be gained hereby, shall have liberty to sew the same into the new channel, by an out-fall sluice or sluices, to be erected at their own expence, either in the new dam proposed in the 7th Article, to be fixed across the old channel, near the new bridge at *Rye*, or to erect the said sluice or sluices in any more convenient part of the banks of the new channel adjacent thereto.

11th. That in case it should hereafter appear, for reasons I am at present unacquainted with, to be more eligible to carry the *Rother* into the *Winchelsea* channel, on the south of the town of *Rye*; this appears also practicable on the same principles; in which case, the sluice proposed at F, should be erected near the place of the proposed dam at K.

OPERATION of the foregoing constructions.

AS the tide will be stopped in the respective channels by the sluices already erected, and proposed to be erected thereon, I find by computation that the whole cavity of the said proposed channels would be filled through the present opening of the great sluice, in the time of a tide, to nearly the same level within as without the great sluice, by a difference or fall no ways prejudicial to navigation through the same.

That the said cavity, containing near five times as much water as the present canal above the sluice, will be sufficient for the scouring of the outward harbour in dry seasons, as the land freshes in rainy seasons will be sufficient of themselves according to all appearances. That the navigation for lighters, &c. up the *Broade* channel, will remain as it now is; and that the navigation of the *Tillingham* channel will be put upon a similar footing, that is, with an opportunity of penning in so much water by the land doors as shall be sufficient for navigation, consistent with drainage; that the navigation up the *Rother* will not hereby
be

be interrupted, because 'tis propos'd on tide of flood to take in as much water, above the propos'd sluice at F, as will float the vessels to *Scotch Flat Sluice*; but to shut out the top of the tides, which will in effect compleat the drainage of all the present extensive flats included within the cross walls, propos'd in Article 3.

That the drainage of the lands by the five waterlings, *White Kemp*, *Guildford*, and *Wenway Sluices*, will be upon a better footing than heretofore, because having little pen upon them from without, the sluices and banks will be subject to less repair, and will admit less sea water in the drains by leakage, soakage, &c. and at low water will have a better discharge, because their out-fall channels will be less liable to silt. The new cut below will, in my opinion, be amply sufficient for all purposes; for though propos'd only 40 feet at bottom, yet, according to the proportions given, will be 80 feet at top, at 10 feet depth; whereas the cut above *Scotch Flat Sluice* does not appear to be above 30 feet at bottom, the sum of all the openings of that sluice being but $26\frac{1}{2}$ feet wide, and yet through this capacity is discharged all the spring and down-fall waters from an extensive flat and upland country. Again, though the sum of the openings of the propos'd sluice at F is propos'd only 11 feet wider than that of *Scotch Flat*, yet as the sills thereof will lay at a medium of 2 feet $3\frac{1}{2}$ inches below those of *Scotch Flat*, and about 4 feet lower than *White Kemp*, which is the lowest of the four upon the marsh wall; that before the water issuing at the sluice F can pen upon the *Scotch Flat*, or the four other sluices before specified, the capacity of the new sluice, taking width and depth together, will greatly exceed the sum of all the rest put together. I mention those things more particularly, because, for reasons before given, I look upon all unnecessary widths, either in the sluices or drains, to be hurtful, it being to no purpose to dig out canals merely for the sea silt to fill up again.

I must also here mention another advantage to the drainage of the lands dependent on the sluices before mentioned; and that is, the danger of the loss of their present out-fall; for though the land waters will always find a way to sea, yet it does not follow that it must be at such a perpendicular height or depth as is consistent with the drainage of the lands; this has actually happened in the course of a few years to the river at *Boston* in *Lincolnshire*; whereas the new out-fall propos'd will be always capable of maintaining its original goodness. And the same reasoning will hold with respect to all the other levels which sew into the old harbour of *Rye*.

I am, however, of opinion, that the tides ought never to be shut in by the great sluice ~~so as to pen upon~~ upon the aprons of any of the sluices for drainage, at a time when any of the levels are under water on occasion of rains or other down-fall.

With

With respect to the *Winchelsea* channel, as an out-fall sluice, as beforementioned, has been erected thereon, within the compass of a few years, near the town of *Winchelsea*, which being very properly placed for stopping of the tides, I am of opinion that nothing further is necessary than to strengthen the walls from the new canal to this sluice, as before mentioned, and to keep this sluice in repair; and that no additional sluice on the main channel, between the aforesaid and the new canal, can be attended with any benefit to drainage, and will be an impediment to navigation up to the town of *Winchelsea*.

I am further of opinion, that no sluice placed to the east of the town of *Rye*, by way of taking in the tides into the channels, proposed as aforesaid, from the old harbour, can be of any use, because I expect that the first winter after the diversion of the land waters, the mouth of the old harbour will in a great measure, if not totally, be choaked up by the sea.

From my view of the works already undertaken, I find many things not yet completed, particularly about the harbour's mouth, the pier heads and the wharfing proposed to extend from the piers to the great sluice, and many things that have gone into disrepair through length of time since the work was done, and for want of letting the sea into the harbour sooner; but as those matters are capable of rectification, I shall at present take no further notice thereof, than in my estimate of the expence that will attend it. And, upon the whole, I am of opinion, that when what has been and is now proposed, is duly executed, that there may be made and maintained 20 feet water at spring, and 14 feet water at neap tides, from the sea up to the head of the present canal, and a proportionable depth as before specified up to the towns of *Rye* and *Winchelsea*; and that for vessels, such as those depths of water will suit, will be a safe, useful, and commodious harbour, and therefore advantageous not only to the towns and country adjacent, but to vessels trading through the *British* channel, and therefore useful to trade in general.

London, February 16, 1763.

J. SMEATON.

An ESTIMATE for compleating the harbour of *Rye*, according to the plan and
report of J. SMEATON.

	£.	s.	d.
To raising the east pier head with stone 5 feet higher than it now is, and coping the same with stone, containing 4589 cube feet, at 3s. 6d. including cramps, comes to 803 <i>l.</i> and for repairing the decayed part, fender piles, &c. 197 <i>l.</i> ; in the whole, - - - - -	1000	0	0
To raising the stone part of the west pier 5 feet high and 4 feet thick, 1080 feet, at 3s. 6d. 189 <i>l.</i> and for repairs of fenders, - - - - -	200	0	0
To compleating and making up the additional part of the west pier, between the stone-work and new head, and for fixing a capstan upon the said head for warping out ships, - - - - -	300	0	0
For repairing and backing up with rough stones the wing, wharfing, extending from the east stone head into the beach fronting the east, - - - - -	300	0	0
To expences in clearing out the harbour's mouth, so as to be 20 feet deep at spring tides, - - - - -	500	0	0
To 2800 feet running of the wharfing, and securing the banks of the present canal from the present wharfing to the sluice, at 2 <i>l.</i> per foot, - - - - -	5600	0	0
To repairs of the wharfing already done, - - - - -	200	0	0
To securing the aprons of the sluice, above and below, with rubble stone, containing 3500 tons, at 5s. - - - - -	875	0	0
To making 4 wharf-wings for preventing the wash of the water from getting behind the wings of the sluice, containing 140 feet running, at 2 <i>l.</i> - - - - -	280	0	0
To additional mechanism, in order to make the drain-gates rise with more ease; - - - - -	250	0	0
To carpenters and smiths work in repairing and strengthening the present great gates, so as to make them more lasting, - - - - -	100	0	0
To capping over the piers of the sluice with <i>Portland</i> stone, containing 3797 feet, at 3s. 6d. cramps included, - - - - -	665	0	0
To making a timber draw-bridge over the head of the present canal, for communicating the road as it now passes over the dam from <i>Rye</i> to <i>Hastings</i> , - - - - -	1000	0	0
	<hr/> 11270 0 0		
To digging out the channel from the new canal to <i>Rye</i> , containing 261653 yards, at 3d. - - - - -	3271	0	0
To removing the present dam, and making such new ones as will be wanted during the progress of the work, and making up the banks, at least to the height specified in the plan, - - - - -	1408	0	0
To widening and deepening the <i>Winchelsea</i> channel, and making up the banks, as per scheme, containing 49573 cube yards, at 2½d. - - - - -	516	0	0
	<hr/> Carried over 16465 0 0		

harbour; the banks or walls to be set at least 40 feet, at a medium, from the brink, and to be raised 25 feet at least above the fell of the great sluice, to be 6 feet top, to batter 2 and $\frac{1}{2}$ to one towards the canal, and 1 and $\frac{1}{2}$ to 1 landward.

To widen, deepen and straighten the *Tillingham* channel from the point aforesaid, so far upwards as shall be necessary to come at a proper place of departure into a new canal, next hereafter mentioned.

To make a new cut or canal to the north of the town of *Rye*, from some convenient part of the *Tillingham* channel aforesaid, to some convenient point of the river *Rother*, the cut to be 40 feet bottom, to agree with the inclined plane aforesaid; its sides to have the same batters as the former; its banks or walls to be raised to the same height, to have the same dimensions at top, the same batters and distance as before described, as far as the crossing of the present turnpike road which leads from *Rye* towards *London*; but if any part of the ground shall not be sufficient to allow the batters, slopes and distance of the banks, before specified, then the sides of the canals and banks to be wharfed up or otherwise supported, so as to preserve the bottom of the canal of the width before specified, and the banks to be made sufficiently strong to hold in the waters to the same height as before specified.

A bridge to be built upon the same turnpike road for crossing the canal, to consist of three arches, one of 13 feet 6 inches wide, the others of 12 feet each; the large opening to be furnished with two pair of gates pointed to seawards, so as to form a navigable lock, and one pair of gates pointed to landward; the other two arches or passages to be furnished each with one pair of folding or falling gates to seaward, and gates to landward. The fells of those gates to be laid even with the proposed bottom of the canal at this place.

To fix a dam across the river *Rother*, near below the point where its course shall be diverted as aforesaid, and to erect a sea-wall or bank from the said dam to some convenient point eastward, upon the present sea-wall of the adjoining marshes, and to carry another sea-wall from the same dam, westward, to abut upon the aforesaid turnpike road; the said dam and walls to be raised to an equal height with the adjoining wall against the said marshes; to be 6 feet at top, and to batter both ways as 2 and $\frac{1}{2}$ to 1.

A navigable sluice to be fixed across the *Tillingham* channel, at some convenient place within half a mile of the bridge. at the ferry near *Rye*, of 13 feet 6 inches in the clear,

with a pair of gates pointing to seaward, and another pair to landward, with draw shuttles or flakers in the latter, and the walls or banks of the *Tillingham* channel, from the said sluice, downwards, to its junction with the canal before described, to be heightened in such manner and proportion as is described for the main channel from the new canal to *Rye*.

A dam to be fixed across the present combined channel of *Winchelsea* and *Tillingham*, at or near the present new bridge at *Rye*; the top thereof to be made up to the same height as proposed for the aforesaid new channel from the new canal to *Rye*, and to have the same slopes as the dam aforementioned, to be erected upon the *Rotber*.

The channel of *Winchelsea*, from the present canal to *Winchelsea Sluice*, to be widened and deepened, so as to be 20 feet in the bottom; to form an inclined plane, so as to fall 2 feet towards the new canal, from the fell of *Winchelsea Sluice*; the batters of it's sides, the heights and slopes of it's walls to be the same as proposed for the new channel from the new canal to *Rye*.

In case the diversion of the land waters shall occasion the out-fall of *Wenway Sluice* to choak up, then a new channel to be cut, and sluice erected, for the discharge of *Wenway Waters*, above the proposed dam, into the *Rotber*.

Proper bridges to be made for communication of the present roads.

TO CAPTAIN PIGRAM.

S I R,

YOUR favour of the 9th instant was duly received, and now comes in course to be considered. As almost two years since I was at *Rye* are now gone over, without any progress being made in those additional works, which were reported absolutely necessary to be done for preserving the harbour, even in the state I found it, it now behoves you to take vigorous measures, and not be impeded by small matters, lest you lose the benefit intirely of what has been done.

That it is necessary forthwith to bring in as much of the back-water as you can procure, appears very evident from what you report, viz. that the new canal is swerved
up,

up, towards the head, 8 feet higher than when I saw it, which is very conformable to what you will find in my report, viz.

“ This canal alone, exclusive of the outer harbour, will take in above 200 fail of vessels, but yet does not contain a sufficient body of water to produce the necessary scourers below; and furthermore, this part of the canal being liable to silt up, by the deposition of mud brought in by the sea, will, in a few years, be choaked up, and rendered intirely useles; the silt being gathered at least 4 feet deep at the head of the canal, since July last, when the harbour was opened. What therefore is *principally* wanting to compleat what I apprehend to have been the original scheme, is to bring the land-waters and freshes of three rivers, that now discharge themselves into the old harbour of *Rye*, through the new harbour, by which means the whole will be kept clear, as appears to me from the following reasons, &c.”

As I look upon the *Winchelsea* waters alone to be insufficient to preserve in the canal a requisite width of channel sufficient for navigation, the grand object is to get possessed of the *Tillingham* water as soon as possible; the natural course of proceeding is this.

1st. To secure the banks or walls of the *Winchelsea* channel from the head of the new canal to *Winchelsea* sluice.

2d. To cut through the dam that at present divides the new canal from the *Winchelsea* channel.

3d. To raise two dams across the *Winchelsea* channel, one just below, but as near as possible the head of the new canal; the other as near as may be to its junction to the *Tillingham* channel, by which means you are enabled to dig out the channel, as directed, from the new canal to *Rye*.

4th. This done, you remove the two dams, and, with as much expedition as possible, raise the dam at *New Bridge* across the united channels.

By this management, you, in the first place, become possessed of the *Winchelsea* waters, towards making a scour, and also that part of *Winchelsea* channel that lays between the present head of the new canal and *Winchelsea* sluice, to add to your reservoir, when you pen in the sea water; and, in the second place, you possess yourself as early as possible of the *Tillingham* water, and of the great increase of reservoir that will follow

follow upon opening this new channel and that of *Tillingham*. With these two you will make something of a figure towards the proposed design, and at the same time bring up vessels to *Rye* by way of the new harbour.

By this method of proceeding the communication of the *Winchelsea* and *Tillingham* waters must necessarily be interrupted during the making this new channel; nor do I know any means of avoiding it, without cutting a fresh channel through fresh grounds, which would not only be a great additional expence upon the undertaking, but only partially remove the objection. If therefore the clamours raised by the seamen and by the country on this occasion are to prevail, I would advise the Commissioners at once to give up the undertaking, and spend no more money upon it; for if the means are not to be used, by which it is to be effected, it is in vain to make any further attempts; but as I can see no material or lasting inconvenience likely to arise herefrom, I will endeavour to satisfy all reasonable and impartial persons on this head.

And first, with respect to the land owners upon the *Winchelsea* channel, those below the sluice will probably expect to be overflowed by the tides rising higher upon them from the new harbour than the old; but it appears, from my levelling notes, taken when there, that when the tide flowed 19 feet 9 inches upon the beacon or staff, at the head of the new canal, it rose within 8 inches of the same level in the *Winchelsea* channel, on the other side the banks, and that when it rose to 20 feet 3 inches upon the said beacon, it rose within 2 inches of the same level in the *Winchelsea* channel. Hence I conclude, that in the greatest tides there is very little difference, or possibly higher in the *Winchelsea* channel than in the new harbour, correspondent to what is usually observed, that weak tides are much spent by a long and intricate course, but when all obstructions are surmounted by a strong tide, that the motion, thus acquired, will lift the tides to a greater height in a river, at a distance from the sea, than near it's mouth: but however this may be in the present case, from the matters of fact above stated, it appears that a much greater flow of tide is not to be expected from the new harbour than the old.

In regard to the sewage of the low grounds at low water, it is very evident that this will be improved, because the fall sluice at *Winchelsea* will then be nearer it's out-fall to low water at sea, and consequently it's course being shortened, it will have more fall in proportion, and thereby penning less dead water upon the apron of the sluice, the water will discharge itself faster through the same openings. It may possibly be objected, that the mud is gathered in the new harbour to a greater height than it's
present

present bottom, at the same distance from the sluice, which will be an obstruction; but the land water will soon cut a channel through the loose mud.

I take it for granted, that whenever these waters are first turned this way, a channel will be opened through the mud, which, once done, there is no doubt to be made but that the water will not only maintain itself a channel through the fresh mud, of as great dimensions as it does in the solid ground, but will even deepen the whole, on account of its greater rapidity.

The same reasons will also take place with respect to the lands that lie upon, or sew, by the *Tillingham* channel, both before and after their re-union with the *Winchelsea*; because, before they will have the whole channel to themselves, and after they will have both a shorter and a better.

It therefore remains that I give my reasons why I don't think the navigation will be spoilt up to *Rye Strand*.

The harbour or place where ships now lie is intirely within the *Tillingham* channel, and which they now find sufficient; it therefore follows, from the established laws of nature, that the same causes producing the same effects, the *Tillingham* waters will maintain the same channel below the new bridge that they do above.

It may be objected, that the united channels below the new bridge, being wider from the union of the two rivers, this channel may grow more shallow, as well as contract in width! I am of opinion that it will not; for since there is constantly matter floating in the water capable of choaking up all the channels, if the land water did not drive it out and keep them open, why does not the *Tillingham* channel widen and grow more shallow? but suppose the channel was to grow somewhat more shallow, yet, for the time, it will be wanted the same expedients might be made use of as is done in several other channels, viz. a hedgehog to raise the mud occasionally, till the sides have contracted themselves to proportionable width. Some small alteration in point of width may also be expected at the old harbour's mouth, but as the effect can only be in proportion to the cause, if we compare the body of water, either coming down or lodged in that part of the *Winchelsea* channel, from the new bridge to *Winchelsea* sluice, with the whole body at a full sea, we shall find the proportion so small as to be almost insensible in its effects; but if by the objections made by the masters and owners of ships at *Rye*, they mean that the present channels are not to be diverted or altered till the mouth of the new harbour

harbour is effectually scoured, and every thing ready to bring up ships to the town of *Rye* by the new harbour; as this is in the nature of the thing impossible to be done but by means of the diversion of the said channels, they thereby desire that the effect may precede the cause, which being contrary to nature, they at once strike at the root of the undertaking, and therefore, as I have already said, if these arguments are to prevail, the best way is to give the thing over at once.

A great deal depends upon the expedition with which these works are performed; for if, while the new channels are digging, the new haven is contracting in width, for want of a sufficiency of back water to keep it open, by such times as they are compleated, the new haven will be afresh to dig, and the work become endless.

Difference of circumstances alter cases. Two summers are now elapsed since my scheme was made, and 8 feet more of mud in the new canal; it is therefore not only necessary to pursue vigorous measures, but to take such methods in performing the work as may the soonest put it in a state of maintaining itself; I would therefore, at the first outset, advise, that the new channel from the new canal to *Rye* be not dug but 35 feet, or at most 40 feet bottom, with slopes as steep as they will stand, as suppose 1 to $1\frac{1}{2}$, according to the quality of the matter, but never steeper than 1 to 1; such a channel will answer all the purposes of navigation effectually; will save a very considerable sum in the first construction; will save a good deal of time, which is now become very valuable, will sooner bring the utility of the undertaking to a proof, and will be as large a channel as the *Tillingham* can in any degree maintain; which will therefore prevent its swerving and contracting in width, while the other channels are compleating for bringing in the *Rotter*; and when that is done, in case the rivers themselves do not make it of the width sufficient, it may be compleated by tide work, after the more necessary parts of the work are brought to bear. Nor is there any doubt but that in the mean time it will take the *Rotter* and *Tillingham* land waters, as the former go all through *Scotch Flat Sluice*, which it has been remarked is no wider, all the passages taken together, than $26\frac{1}{2}$ feet; and as to the *Tillingham*, its capacity when the tide is checked by the sluice proposed to be built thereon, will be contained in one of the slopes, for even a 35 feet bottom, with the steepest batters, will produce a 65 feet top, and a 40 feet bottom, with batters of 1 to $1\frac{1}{2}$, will produce a river 85 feet at the grafts.

It will here be naturally enquired, whether I would build the sluice proposed upon the *Tillingham*, before it is made to communicate with the new harbour? I answer, not, for as the tides will go up in the same manner, whether proceeding from the new harbour or the old, the use of that sluice will be entirely to check the tides from coming in too rapidly

rapidly at the great sluice by having too much room to expand; but as this will not be the case till the communication with the *Rother* is made, till then it will be useful by enlarging the reservoir.

With respect to the works at the harbour's mouth, you know it was always my opinion, that an attempt to stop the beach absolutely from moving from the west towards the east would be a fruitless and endless task; for let the groins be extended to what length they would, they would fill with beach as fast as they could be raised, and the overplus drive over into the harbour's mouth; I therefore thought it best to let the beach drive away gradually as it came, and in consequence that the extension of the west head could be of no further use than to steer the beach clear of the east head till the wind came so far out to southwards as to tend to heap up the beach upon the shore, rather than drive it along the coast, which end seemed to me very sufficiently answered by the pier as it stood when I saw it, especially with the low groin extended therefrom southwards; for it always seemed to me, that in case the pier was carried out further than absolutely necessary for this purpose, that the quantity of beach that will always be left scattered about the mouth of the harbour, after every south-westerly gale of wind, as it were in its passage, will be too far in the expanded space without the east head, to be carried out by the scours, and then a southerly or south-easterly gale brings it right into the harbour: these have been my notions about this affair, and which have been before expressed.

But as I have not yet found any solid ground-work, upon which I am able to determine how the sea will act in all possible cases; and as you have been pleased to try the experiment of a different procedure, I would advise you not to lower those groins till you are very sure they are upon the whole hurtful; and if so, the thing determines itself; consider also, if hurtful to the harbour, how far they may be beneficial to protect the beach from being carried away to the eastward of the east pier, or how far that may be protected by other means. It is one thing to advise an erection not to be made, and it is another to advise its demolition when made, before it has been sufficiently tried.

You further inform me, that the old timber wharfing, by getting bare, tumbles down faster than they can put it up new. Let me once more recommend to you the use of rubble stones for defending the sides of your harbour instead of timber, not walled, but thrown in so as to form a natural slope. The effect thereof on many repeated trials I have never found to fail; and I may say that I saved the two piers of *London Bridge*, whereon the great arch rests, from being undermined, and thereby the arch from falling, the very season I was at *Rye*. I am of opinion, that had 300*l.* been applied in time in rub-

ble stone behind your east pier, as mentioned in my estimate, that it would have saved greater expences, and been a lasting repair ; but this, as well as several other derangements that happened in the mean time, I suppose must be imputed to the unseasonable stoppage of the bill the first season it was applied for.

I am, with great respect to the Commissioners,

S I R,

Your most humble servant,

J. SMEATON.

Austhorpe, December 29, 1764.

RIVER WENT.

Minutes of a view of the river *Went*, by JOHN SMEATON.

HAVING taken a view of the river *Went*, *Yorkshire*, from *Went's Mouth* to *Norton Mills*, there appears to me a sufficiency of fall for draining not only the valley of the river *Went*, but of those lands that have their sewage into the same, and which appear to be of a very considerable extent. It appears to me, also, that the principal defects of the present drainage, arises from the great crookedness of the river, joined to its being too shallow, and a general want of capacity for taking off the water from so great a tract of country; the out-fall sluice is also of too small a capacity for the drainage of such an extent of country, but seems nearly adequate to the present drain; the mechanism of its present doors, however, is very defective, and they are too low. The river *Dunn's* water having over-topped the same, the banks near the sluice, which ought to defend the valley of the *Went* from the floods of the *Dunn*, being too low and out of repair, have suffered great quantities of water in the late floods to pass into the same. The drainage of the *Went's Valley* is further annoyed by an influx from the river *Dunn* in time of great floods, through a low slide of ground between *Brafit Common* and *Flaxley Carr*, and from thence proceeds down by way of a drain called the *Fleet* into *Went*, a little above *Topham Ferry*; for as *Brafit Common* is frequently overflowed by the land floods of the *Dunn*, (and sometimes even by high tides, according to my information,) and as *Asb Carr*, which borders upon *Brafit Common*, and is the highest part of the slide, lays lower than the surface of the dam in high floods, the water makes its way through the drains and hedges in great quantities into *Flaxley Carr*, and from thence by the *Fleet Drain* into the *Went* as aforesaid. There seems to have been formerly some attempts to have prevented the water of the *Dunn* from taking this course, by raising a fence bank somewhat more considerable than common, between *Asb Carr* and the inclosures that lay east and north-east thereof, which so far at present answers the purpose, that by raising dams with fods, &c. in the gateways and low places, a great deal of water was prevented from passing, that otherwise would have passed this way during the great floods, last Christmas; and, was this bank raised, so as to be of sufficient height and strength, would effectually answer the purpose; but the same purpose would be more conveniently answered by constructing a new bank, with proper tunnels, for the drain across the head or south end of *Asb Carr*, from the inclosed ground that lays upon the west side thereof, and abutting upon *Brafit Common*, extending the same along or parallel

lel to the south hedge of the inclosure, on the east side of *Ash Carr*, which also abuts upon *Brafit Common*, to the side of *Brafit Fields*, being in length, by estimation, about 250 yards: this bank, in one position or other, not only appears necessary for securing the drainage of the *Went's Valley*, but will greatly improve that of a considerable tract of land laying in the shade aforesaid, particularly about *Flaxley Carr*, which, except a part of the top waters which are run off down the *Fleet* into *Went*, and by another drain leading to the outside of *Syke House Bank* to the south end thereof into the *Dunn*, depends altogether upon a small tunnel called *Hell Wicket Clough*, no more than 8 inches by $12\frac{1}{4}$, for running off their bottom waters through *Syke House Bank* into the internal drains, and thence into the *Dunn* by *Black Sea Clough*, which clough runs three days on the decline of a flood before *Hell Wicket Clough* is opened. It further appears to me, that the drainage of *Brafit Common*, and the lands dependent thereon, will receive no prejudice by the bank before proposed, because *Brafit Common* lays several feet lower than *Ash Carr*, both which drain the contrary way, or southward into the *Dunn*, the present fence bank before mentioned being the line of partition of the two drainages, at all times, except in extraordinary floods as aforesaid.

Although from this view now taken, I am convinced of the practicability of draining the valley of the *Went*, yet the depth and capacity of its main drain, together with the requisite height, and dimensions of its banks and sluice, cannot be ascertained without an actual level taken thereof; and, in order to ascertain the quantity of land concerned in this drainage, as well as the general directions and length of the drains to be new constructed or amended, and thereby to come at a correct estimate of the same, it will be necessary to take an actual survey of the river *Went*, from its mouth to *Norton Mill*, describing the banks, sluice, and main drains that fall into the same, upon a sufficient scale to express the particular loops of the river; and also an outring or flood line of such parts of the several lands that drain into *Went*, that are liable to be flooded thereby, or for want of a sufficient fall into the same; which outring does not need to be traced with that correctness, that the river itself ought to be laid down, but preserving, however, the general bearing between the river and its correspondent part of the outline. The taking of the levels I can myself undertake, if the gentlemen concerned desire it, the surveying part I would recommend to be done by a skilful land surveyor.

Warrington, 31st March, 1764.

J. SMEATON.

N. B. As the present river is wanting in capacity, and its course so meandering that it is likely to measure by its loops double the right line, I apprehend it will be less
 expence

expence to make a new cut the greatest part of the length, than to sufficiently enlarge the present river, which cut may be so contrived as to strike a general mean between the properties.

MINUTES taken upon the River *Went*, in levelling the same, from the River *Dunn*, at *Went's Mouth*, to *Norton Mills*, the 7th, 8th, and 9th of May, 1764.
by JOHN SMEATON.

Places of observation.	Rise of the river's surface.	Widths taken at promiscuous places.	Depths taken at promiscuous places.	Height of lands above the water's surface.	Rise of the last winter's flood above the river's present surface.
From the surface of the river <i>Dunn</i> to the threshold of <i>Went's</i> doors, which was $7\frac{1}{2}$ inches under the water's surface there, - - - }	Ft. In. 1 5 $\frac{1}{2}$	Bridge 14 9 other places from 10 to 18 }	- -	Near the <i>Dunn</i> 11 9	Floods of <i>Dunn</i> 13 2
From <i>Went's</i> doors to <i>Hooden Dyke</i> , - - - }	0 9	from 12 to 18	from 0 8 to 3 0	mean height 6 to 5 $\frac{1}{2}$	<i>Went's</i> floods about 6 feet.
From <i>Hooden Dyke</i> to <i>Baron Croft</i> , - - - }	3 4 $\frac{1}{2}$	from 12 to 19	from 3 0 to 1 3	from 4 0 to 1 6	from 4 0 to 3 7
From <i>Baron Croft</i> to <i>Topham Ferry</i> , - - - }	0 9 $\frac{1}{2}$	15 0 bridge 14 2	from 1 8 to 2 0 }	- -	- -
From <i>Topham Ferry</i> to <i>Lake's Mouth</i> , - - - }	3 6 $\frac{1}{2}$	from 14 0 to 16 0	from 4 0 to 2 0	from 1 6 to 1 2	from 2 6 to 3 0
From <i>Lake's Mouth</i> to <i>Clough Bridge</i> , at the low corner of <i>Norton Common</i> , - - - }	1 9	from 13 0 to 14 0	from 3 0 to 1 2	from 1 3 to 0 6	from 3 0 to 2 6
From <i>Clough Bridge</i> to the departure of the <i>Went</i> from <i>Stubb's Common</i> , - - - }	2 4 $\frac{1}{2}$	from 16 0 to 15 0	from 1 10 to 1 0	from 0 6 to 2 6 }	- 2 6
From <i>Stubb's Common</i> to <i>Norton Bridge</i> , - - - }	3 7	from 9 0 to 16 0 }	from 1 0 to 1 8 }	from 2 0 to 3 0 }	from 2 6 to 3 0
From <i>Norton Bridge</i> to the floor of <i>Norton Mill Race</i> , - - - }	1 4 $\frac{1}{2}$	double course. }	- -	from 4 0 to 3 0	from 4 0 to 3 0
From the river <i>Dunn</i> to <i>Norton Mill</i> , - - - }	19 0				

Hence

Hence it appears, that from the floor of *Norton Mill Race*, to the surface of the river *Went* at *Clough Bridge*, there is a fall of 7 feet 4 inches, and from thence to the threshold of *Went* doors a fall of 10 feet 10 inches, which added together make a fall of 18 feet 2 inches from the floor of *Norton Mill* to the threshold of *Went* doors, and from thence to the surface of the *Dunn*, there was a fall of 10 inches; but as it was a neap tide, and not then low water, I suppose the *Dunn* would ebb a foot lower, so that from the tail of *Norton Mill* to low water in the river *Dunn* at *Went's Mouth* at a neap tide, in summer, we may reckon a fall of 20 feet.

The dimensions of the sluice called *Went's* doors, are as follow :

					feet.	inches.
The width between the walls at top is	-	-	-		12	0
Ditto at bottom	-	-	-		10	0
The width of the opening between the gates at top is	-	-	-		8	7
Ditto at bottom	-	-	-		7	3



WOMERSLEY DRAINAGE.

The REPORT of JOHN SMEATON, Engineer, concerning the Drainage of the low grounds in the manor of *Womersley*, belonging to STANHOPE HARVEY, Esq;

HAVING taken a view of the lordship of *Womersley*, with respect to the drainage thereof, the 16th and 17th of July, 1764, it appears to me as follows.

1st. That the middle of the manor, through which the drain called *Bradley Dyke* passes, is in general the lowest part thereof.

2d. My own observation also agrees with information, that the piece of ground called *Bradley*, is the most liable to be flooded of any in the lordship.

3d. That from the run of the water in *Bradley Dyke*, which in many places is pretty quick, at the same time that this drain is narrow, shallow, crooked, and much obstructed, there seems to be a fall of several feet in the course thereof from *Bradley* to the brook called *Lake*.

4th. That there is also a considerable fall from the mouth of *Bradley Dyke*, to the beginning of Mr. YARBOROUGH's lands, bordering thereupon at the *Calf Garths*.

5th. That the sewer called *Blowell*, which in general skirts the lordship on the north, and falls into *Lake* at the easternmost point thereof, is very well calculated to answer the purpose of a catch-water drain, to carry off the barrier waters, without suffering them to pass into the internal parts of the manor; but passing in general through higher lands, seems not well adapted for a main drain, except for some particular parts, which will hereafter be pointed out.

6th. That the rivulet called the *Beck*, whose continuation after it joins *Bradley Dyke* is called *Lake*, and which makes its way through the southern side of the lordship, is in like manner well calculated for a catch-water drain; but as the *Beck* likewise passes through higher lands, and also carries the springs and flood water from the upland country, it is therefore less adapted for the purposes of a main drain for the interior parts of the manor.

Hence

Hence I am of opinion, that the lordship in general will be drained in the best manner by a middle drain, calculated more effectually to answer the purposes of the sewer called *Bradley Dyke*.

In order to give this drain all the consequence possible, I would propose its out-fall to be as low as may be, that the declivity in the *Lake* arising from its being loaded with the upland waters, as well as from its crookedness and want of dressing, may be in a great measure avoided. For this purpose, I would recommend that the out-fall of the new drain be carried down to the easternmost part of an inclosure, called *Old Ing Spring*, that is, to the commencement of Mr. YARBOROUGH's lands, which begin with the *Calf Garth* next adjoining; from this point I would propose to carry the new drain to *Bradley*, as much as may be in a right line, without interfering with other property, to pass as much as may be through the lowest grounds, and so as to be as central as possible; with this view I would propose to carry it from the easternmost point of *Old Ing Spring*, marked in the plan *a*, obliquely for a few rods till it meets the hedge-row between the *Old Ing* and *Old Ing Spring*, and to follow that hedge-row to *b*, from thence to pass in a straight line to the south-east corner of the *Sedgels* at *c*, to follow the south hedge thereof to *d*; from thence in a straight line through *Bell Fields*, *Stocking Pobill Spring*, and *Stockings*, to the south-west corner of *Ox Stockings*, between *Grayson Close* and *Bradley Dyke* at *e*; from thence in a straight line cross *Broad Oak Spring Closes* and *Broad Oak Spring*, to the point *f*, between Mr. SAVILLE and Lady BELT's lands; from thence in a right line cross *Hodshon Crofts* to the road, and to cross *Bradly Dyke*, a little above *Bradley Bridge*, to the *Sedgells*, at *g*; and from thence in a right line, so as to avoid *Bradley Dyke*, into *Bradley*, at the east corner thereof at *b*; from hence branches may be carried at discretion to the more remote parts of the lordship, as for example, one from *b*, across *Bradley* westward, to *i*, and from thence cross low moor to *k*, where it will receive the waters from the springs rising near that point, and also will conveniently receive the drainage from *Northings*. Another branch may be carried from the said point *b*, cross *Bradley* north, through *Pipper Carr*, and the rest of *Woodball Farm*, to the point *l*, where it is calculated to receive the down-fall waters from the large piece of low ground called *Gale*.

With respect to *Blowell*, the *Beck*, and *Lake*, I would advise them to be continued in their present course, and their banks to be made up, and strengthened where necessary, towards the interior parts of the lordship, in order to keep out the barrier waters from penetrating thither, and thereby not only contributing to flood the lands, but to load the internal drain.

The bottom of the proposed drain at its out-fall, I would advise to be made as deep as the bottom of the *Lake* thereabouts when scoured, and to be carried upon a dead level to about the length of *Stocking Pothill Spring*; from thence to advance upwards upon a regular inclined plane, so as to be full 5 feet deep on entering *Bradley* at the point *b*, to be 6 feet wide in the bottom, and the sides to slope or batter 1 foot backwards in 1 foot high; so that supposing the mean depth to be 6 feet, it will be 18 feet wide at top, and there will be 8 cube yards in 1 yard running, and in every acre of 28 yards long 224 cube yards, which at $1\frac{1}{2}d.$ per yard will cost 28*s.* an acre, or 1*s.* per yard running; that is, 88*l.* per mile, and for 2 miles and 1 furlong, which is the length of the proposed drain from the point *a* at *Lake*, to *b* in *Bradley*, will cost 187*l.* exclusive of clearing the ground of wood and roots, and exclusive of such bridges as may be necessary where the roads cross the same, which are four in number.

The branch drains need not be above 4 feet bottom, carried upon a regular inclined plane, so as to be at their upper end at least 4 feet below the surface of the lands to be drained thereby.

That part of the lordship about *Wye Lands*, *Kidcoats*, &c. which now drain into *Blowell*, will drain much better into the new proposed drain, by a cross cut from *South-Lane*, through *Katele's Crofts*, to the drain between *Bell Fields* and *Hare Springs*; but the lands lying more eastward about *Mitchel-Lane*, may continue to drain into *Blowell*, being by this road nearer this out-fall, provided the obstructions between *Hodsham Gartbs*, where this drainage comes in, and the out-fall of *Blowell* into *Lake* are effectually remedied, and that drain deepened from the bottom of *Warfield Wood* upwards to the said point, in which space a good deal of fall is at present lost.

These methods steadily pursued, and strictly adhered to, will in my opinion put the lordship in as good a capacity of drainage as it is capable of, and which will be fully effected when the river *Went* is made a sufficient sewer for the general drainage of the lands lying thereupon.

N. B. The business herein attended to is the main drain and the diversion of the barrier waters; but it must be understood, that the benefit arising therefrom cannot fully take place till the smaller ditches and sewers that divide and intersect the lands are thoroughly scoured, and such further cross cuts made to lead the water from low places by the most direct road into the main drain, as experience and further observation shall shew to be necessary.

Womersley, 18th July, 1764.

J. SMEATON.

MISTERTON SAS AND SNOW SEWER.

The REPORT of JOHN SMEATON, Engineer, upon the case of *Misterton Sas* and *Snow Sewer Drain*, belonging to the honourable the Participants of *Hatfield Chace*, from a view taken thereof 14th August 1764.

MISTERTON SAS is the out-fall sluice of the river *Idle*, built upon *Vicar's Dyke*, about half a mile from the *Trent*. This sluice is furnished with two pair of doors, both pointed towards the *Trent*, so as to compose a lock for navigation of vessels, serving them to pen from the tide water into the drain, and thereby occasion either pair of the doors to be shut. The neat width of this sluice is 17 feet 8 inches, and its height above its threshold a little more than 16 feet. The question concerning it is, as I apprehend, whether an addition of water-way at the *Sas*, in time of floods, will be of service in reducing the height, and consequently the weight and pressure of the water at those times against the great bank called *Vicar's Dyke Bank*, which defends the level of *Hatfield Chace* against the floods of the river *Idle*.

OBSERVATIONS.

1st. The time that I was at the *Sas* the tide was out, all the doors open, and the land water had its free course through the same; the depth of water running over the threshold of the doors to landward was 4 feet 7 inches, and the water's surface had a fall from head to tail of the sluice of above $4\frac{1}{2}$ inches, consequently the threshold of the doors to Trentward were below the surface of the tail water 4 feet $2\frac{1}{2}$ inches.

2d. Being met at the *Sas* by Mr. WILLIAM CROMPTON, he having made several exact observations upon the state of the waters here during the course of last winter, informed me that the 21st of May last (which was the day before the moon quartered) he observed that the tide rose at the *Trent* 5 feet before it sensibly rose at the *Sas*, the tail water at the *Sas* being then the same height as this day, viz. 10 feet 10 inches below the S. E. corner of the land wall at the *Sas*; now had there been no run of water through the *Sas*, then the water would have been upon a level from the *Trent* to the *Sas*, and of consequence,

consequence, it would have appeared that the threshold of the sluice would have been $9\frac{1}{2}$ inches higher than low water mark at the *Trent*; but as the run of water through the sluice was then considerable, as it was this day, it follows that as soon as the water begun to find any stoppage at the sluice to its discharge into the tail drain by the rising of the tide, that the water at the sluice would begin to swell or rise, though it still preserved its motion downwards, and consequently that it would begin to swell before the water of the *Trent* was got up to the same level; now if we allow 2 or 3 inches for this declivity from the *Sas* to the *Trent*, which must be added to the former $9\frac{1}{2}$, we shall have about 12 inches that the thresholds of the sluice lay higher than low water mark at the *Trent*.

3d. Mr. CROMPTON also shewed me a mark that the land waters were at on the head of the sluice the day before the bank broke at *Idle Stop* last winter. This mark I found to be 5 feet 5 inches above the present head water, and consequently (allowing $4\frac{1}{2}$ declivity on on the tail) 5 feet $9\frac{1}{2}$ inches above the present tail water. He also shewed me a mark, being the height of the water then in the tail of the *Sas*, when the doors were open and running with a full bore; and this mark I found to be 5 feet $1\frac{1}{2}$ inch above the tail water, consequently the fall of water at the *Sas* was then at its greatest stream 8 inches.

4th. The width of *Vicar's Dyke*, at a medium between the *Sas* and *Idle Stop*, was about 38 feet at the water line, the depth at a medium from 3 to 4 feet, and the water having a smart run all the way, I suppose by estimate that the fall of water from *Idle Stop* to *Misberton Sas* was at least 1 foot per mile; that is between 3 and 4 feet, as I estimate the distance between three and four miles.

DEDUCTIONS.

AS it appears from the preceding observations, that the pen or head of water at *Misberton Sas*, occasioned by want of capacity, never exceeded 8 inches in the greatest extremes of floods; hence it would seem that the flood water was never raised more than 8 inches higher than it would otherwise have been, had the *Sas* been as wide as the river; and this conclusion would be quite just, in case the flood water had been confined on both sides, so as to be obliged to go off as fast as it came down; but as it was at liberty to

spread over the lands, where it did not find a passage to its out-fall so fast as it came down, it must keep accumulating till the discharge was equal to the influx.

Now it must be allowed that had the *Sas* been of a greater capacity, it would have run a greater quantity of water upon a given declivity; consequently, from the first approach of floods by continually running more water, the accumulation would have been less, and the rise of water less against the banks, which in all probability would have preserved them from breaking at *Idle Stop*. It is by no means however hence to be inferred, that though the sluice had been as wide as the river, that the floods would have been carried off as fast as they came; for, in the first place, whenever the *Trent* floods or tides over-rode the land waters, the sluice could not run at all, let its capacity be what it would; and at other times, as the effects depend jointly upon the capacity of the sluice to discharge, and upon the drain to bring the waters to it; and as *Vicar's Dyke* appears to be defective in point of depth, it must have had a considerable share in the obstruction: for as from observation the 4th, there appears a considerable fall from *Idle Stop* to the *Sas*, this cannot be otherwise occasioned than by a rise of the river's bottom, which thereby holds up the water, and must obstruct its free passage in all degrees of floods: whether this obstruction has gradually arose by means of weeds, &c. or it has been originally made so, may be a question; but we may reasonably suppose it was originally made so; for was this part of the river deepened, it would draw off the water from the higher parts of the river in dry seasons to a greater degree, so as to incommode the navigation, and perhaps at some times to put an entire stop thereto for want of water over the shoals above.

Upon the whole, then, I look upon the enlargement of the water-way at *Misterton Sas*, to be an adviseable step, and that it may be done in a proper degree relative to the drain, even upon a supposition that it was deep enough, we are to enquire what capacity the sluice ought to have had.

The width of the drain 38 feet at the water line, supposing it to carry 3 feet water, it will batter 3 feet each side, and will have a 32 feet bottom: this ought to have been the width of the water-way, supposing the thresholds laid as low as the water-mark. The greatest extremes of floods rise per observation 10 feet above the thresholds of the sluice, and consequently 11 feet above low water mark, so that 11 feet multiplied by 32, the proper width, given 352 feet area, for the water-way; but 10 feet the present height, multiplied by 17 feet 8 inches, present width, gives 177 feet area nearly; which, being nearly half of the former, it shows that the present water-way should be doubled, if laid at the same depth.

This

This enlargement may be made three ways :

1st. By four draw-gates of 4 feet 6 inches wide each. 2d. By two pair of pointed doors, placed near together, one pair pointed to *Trent*, the other landwards, which latter may be gaged to the height requisite for navigation.

3d. By one pair of doors pointed to *Trent*, and by a fixed over-fall or weir, gaged to the height necessary for navigation.

The doors in the 2d and 3d method may be the same width as the present *Sas*, the threshold being laid at the same depth, or about 16 feet wide if laid down to low water mark ; but in the 3d method, supposing the height necessary for navigation to be 5 feet above the present cill, then the length of the crown of the over-fall must be 35 feet, for then when the floods rise 5 feet above the top thereof, there will be 175 feet area of water-way, which, with 177 feet at the *Sas*, will be 352 feet, as required.

The first method has preference in point of expence, but the gates will want opening on the approach, and shutting on the decline of a flood ; and as these are not sudden, or of very short continuance, may easily be done.

The second method will be nearly as cheap as the first, and will need attending at the same time.

The third method will be somewhat more expensive than either of the former ; will be preferable on account of needing no attendance ; will do the same office on the extremes of floods ; but will be of less service in discharging the water on the decline of floods ; which, though of no immediate consequence to the banks when below a certain height, yet in case of succeeding rains, the nearer the former are run off, the more room for those that follow.

That the third method will be inferior in point of discharging water on the decline of floods, appears thus: suppose the water reduced so as to make 1 foot over the crown of the weir, its area of discharge will then be 35 feet, whereas it would make 6 feet over the threshold of the gates or doors, and upon 17 feet 8 inches wide, 106 feet area: the weir indeed is not confined to 35 feet long, but in this case it would be required nearly three times as long to do the same thing.

The ready discharge of the water on decline of floods will be very beneficial to drainage of the lands, which drain into *Idle* or *Vicar's Dyke*, and therefore ought to tribute if done on that principle.

ON SNOW SEWER.

THIS drain leads the down-fall water from that part of the level adjacent to *Idle Stop*, &c. on the south side of the isle of *Axbolme*, to a place called *Ferry*, where there is a sluice called *Ferry Sluice*, by means of which the water of this sewer is discharged into the river *Trent*, and is the highest sluice upon the river belonging to this level, and consequently has the least natural fall; it was however necessary, on account of the drainage of that part of the level laying on the south side of the island, the high land of which abuts eastward on the river *Trent*, and thereby prevents a natural communication of internal drains to carry the waters of these parts to a lower point upon the *Trent*, without carrying them a great way round about the west end of the island.

This drain is from 15 to 20 feet wide at the water line, and when I was there carried a full body of water, which at three miles distant from the sluice had for the most part a slow run, except in some places where it appeared to be standed; there the motion was somewhat more lively; but as the drain was in most places horse belly deep, quite free from weeds, and no capital obstructions, there appeared upon the whole to be no remarkable less of fall. As we approached nearer the sluice, the water was in a manner stagnant, the doors being shut by the tide: in this state, the water was just beginning to get upon the surface of the commons from a mile to a mile and a half west of the sluice, which hence appears to be the lowest. I observed at the same time that the water was 3 feet 6 inches deep upon the land apron of the sluice.

The sluice consists of two doors of 6 feet water-way each; but the tide being in, and the sluice-keeper absent, there was no coming to the knowledge at this time how the thresholds of the sluice lay with respect to low water mark in the *Trent*; accordingly orders were given that this should be taken at a proper opportunity, and the following were in consequence sent me.

				Feet.	Inches.
Above the threshold,	-	-	-	2	2
On the floor,	-	-	-	2	9
The fall of water,	-	-	-	5	9

Mr. FORSTER suspecting the above might not be rightly taken, desired me to go over again, but, being engaged at that time, sent my clerk, who took the levels the 9th of September,

tember, being the day before the full moon, and consequently between the neap and spring tides : his account was

							Feet.	Inches.
The surface of the water in the <i>Trent</i> at low water, above the top of								
the threshold,	-	-	-	-	-	-	0	2
Thickness of water going over the threshold,	-	-	-	-	-	-	0	6
He was further informed that at dead of neap the surface of the <i>Trent</i> , at								
low water, was lower by	-	-	-	-	-	-	0	6

From the last observations it appears, that the threshold of *Ferry Sluice* lays higher than low water mark at dead of neap (which here it seems makes the lowest water) by 4 inches ; and allowing 7 inches for the height of the threshold above the floor, (according to the former observations) and taking this from 3 feet 6 inches (measured by myself) upon the land apron, there will remain 2 feet 11 inches descent from the surface of the lowest lands to the threshold of the sluice; and 3 feet 3 inches from ditto to low water mark, neap tides. Hence it appears, that as the fall is but barely sufficient to furnish the means of drainage, the whole ought to be constructed upon the nicest principles, and kept in exact order.

It does not appear to me, that any great matters can be done till the sluice is rebuilt, further than an effectual scouring of the drain, and deepening where found necessary ; and if banks of $2\frac{1}{2}$ or 3 feet high were raised against the low commons, it would prevent their being overflowed by the water coming down from the westward, when the *Trent* floods over-ride the drain, and keep the doors constantly shut ; but then tunnels with valves next the drain must be laid through such banks, to take off the down-fall from the commons, where the water of the drain becomes lower, otherwise such banks will be a means of retaining the water upon the lands, as well as in preventing their being overflowed. A further temporary expedient might be, to turn as much of the water as may be from the western parts, towards *Austhorpe Sluices*, which, laying lower upon the *Trent*, afford a better fall.

When *Ferry Sluice* is rebuilt I would advise its floor to be laid lower by 1 foot 6 inches, that is, 1 foot 2 inches below low water mark at neap tides, and to be made at least 15 feet clear water-way, to be shut by a pair of pointed doors.

I know this practice will be opposed, upon a supposition, that being laid so low it will not run so long, and will be more liable to warp.

But it is very plain, that was the orifice a mile deep, it would always run when the water within was higher than the water without, and that at all other times the doors would be shut; and this will equally be the case if laid high, but with this difference, that by being dammed up by the floor and threshold, it will not run when the water of the drain is lower than the threshold, though higher than that of the river. To make the advantage clear, let us suppose 1 foot water going over the threshold of the present sluice, which being 12 feet water-way, the section of the column of water passing will be 12 square feet; now suppose the water at the same height within, and the floor 1 foot 6 inches deeper, then it would run with the same velocity in a column 2 feet 6 inches in thickness and 12 feet wide, which makes 30 feet area of the column; so that in this case the sluice would run as much in one tide as in the other it would run in $2\frac{1}{2}$ tides; but if the width is increased to 15 feet, the area will be $37\frac{1}{2}$ feet, so that it will then run more water in one tide than the present one in three. Again, when the present sluice is run dry, there will be a column of 1 foot 2 inches thick upon the threshold of the new, whose area will be $17\frac{1}{2}$ square feet, which will vent as much water as the present sluice will do when it has 11 inches water upon its cill; so that the construction proposed will not only, at all heights of the water, run much more in quantity, and thereby vent the water quicker, but run it down to a lower surface than it possibly can be by the present construction.

With respect to ways, suppose the old and new sluice both warped up to the same height to both without, and the water at the same height to both within, that is both to act from the same drain; it is plain that the old sluice cannot act till a channel is made through the warp, whose bottom is lower than the surface of the water in the drain; it is also plain that the new one will begin to act at the same time; the only difference will be, that as the warp will lay 18 inches deeper against the doors of one than the others, there may be some little more trouble in clearing the warp from before the doors, so as to suffer them to open at the very first starting; but after each has begun to run, and cleared away a part of their warp, the new sluice will always have the advantage of the old one, because, by carrying a greater body of water, it will open its channel quicker and more effectually keep it open at low water, so long as it continues to run.

The sluice being thus constructed, it will be necessary to deepen the drain, making the bottom 15 feet wide, and to carry it as near as possible upon a dead level with the threshold for 2 miles; from thence it may be regularly inclined towards its head: this being done, in my opinion, it will do its duty without suffering any of the lands to be overflowed by the *Trent*.

Austhorpe, 19th September, 1764.

J. SMEATON.

EARL OF KINNOUL'S LANDS.

The REPORT of JOHN SMEATON, Engineer, concerning the Works for the Defence of the Lands of the Right Honourable the Earl of KINNOUL, laying upon the Rivers *Ammon* and *Tay*, *North Britain*.

1st. **I**T appears to me that the greatest part of the damage done by floods upon these lands, is owing to the shallow channel of the river *Ammon*, and the insufficiency of its banks.

2d. That, in order to cure these defects, it will be necessary to carry a bank from a point of land marked out, about half an *English* mile above *Ammon Bridge* down to the east abutment wall of that bridge, and from the said east abutment to carry a bank coasting the east side of the river *Ammon*, at a proper distance to the point of land laying between the mouth of the *Ammon* and the *Tay*, which bank ought at a medium to be about 4 feet high and about 20 feet of base, the slopes to be sodded on both sides, or that next the river to be covered with large gravel.

3d. That as the aforesaid work will be of equal and immediate advantage to the grounds now liable to be flooded by the waters overflowing the banks of the *Ammon*, which are without the border of the estate of the Earl of KINNOUL, (and upon which the said banks are proposed to be made) therefore the proprietors to be at a joint expence with the Earl of KINNOUL for the compleating thereof.

4th. But in case the said proprietors do not chuse to be at their proportion of expence, then I would advise the Earl of KINNOUL to make good the breach that has been made in the land contiguous to the bulwark erected at the end of the new road leading from *Perth* to *Ammon Bridge*, and to make the whole effectual, to take down the remains of the present bulwark, and to make the whole of rough or rubble stone from the quarry, added to the present materials thrown together bank fashion, so as to slope $1\frac{1}{2}$ feet base to 1 foot perpendicular towards *Ammon Bridge*, and $2\frac{1}{2}$ feet base to 1 foot perpendicular on the side next *Perth*, to make the same 2 feet lower than the surface of the ground on which the said bulwark abuts in the middle between the abutments, but to raise the same somewhat higher than the said surface at the ends where the bulwark abuts upon the same, and to extend the rubble work 1 rod at each end on the plain surface, and also to

line the banks or abutments with rubble for 1 rod above, and 2 rods below the bulwark at each end; which said bulwark is intended to confine the waters of the *Ammon* or *Tay* in moderate speats from flowing down the old road, but in high floods to break the rapidity of the current, and to admit the same to have an easy passage over the bulwark.

5th. In regard to the great bulwark, which was erected at the joint expence of the Earl of KINNOUL and the town of *Pertb*, in order to preserve and regain the lands from the incroachments of the river before which it has been raised, I am of opinion that the lands might have been secured in a much easier and cheaper method, as hereafter described, and with respect to the regaining of lands they could never be worth the purchase: it further appears to be built of very bad stone, and therefore will be subject to a considerable annual repair, greater than will support the banks intended to be supported thereby; yet as some good has been produced from it, though not adequate to the expence of building or maintaining it, yet I would not advise any erasement thereof, but to leave the same to such events as the floods and weather may produce, and which in a state of rubbish, by keeping the channel of the river at a distance, will tend to lessen the repairs, which otherwise might be necessary on the said banks; and whenever the river shall begin hereafter to make any depredations on the land, to apply the cure immediately to the part affected, which I would advise to be done in the following manner:

Let a quantity of rubble stone be brought from the quarry, the more angular, rough, and irregular the better, and at a medium as big as a large cabbage; let as much be thrown up against the broken place (almost as steep as it will lay) as will form a natural slope against the bank as high as ordinary floods reach, or as the surface of the lands where lower, sloping away the land above the rubble where higher, observing to avoid all jetties and protuberances as much as may be, so as to give the water as free a passage as possible. In general I would advise my Lord KINNOUL, in case of breaches or incroachments upon the land by this or any other river, not to have recourse to jetties, or walls of masonry, but to line the banks with rubble thrown in, so as to form a natural slope, and the length of the work the nearer it is to a parallel direction with the current the better, by this means the quantity of materials necessary to form a jetty, breakwater, or bulwark (which being designed to resist and oppose the current must be made stronger) being disposed along the face of the bank, will in general be sufficient to defend the whole length that could be expected to be effected by the jetty; and with this difference, that the edge formed by the jetty itself, generally forms a pit or incroachment upon the land just below; whereas the work disposed in a parallel direction to the current equally protects and equally resists; so that the wreck and fullage of the river in time filling up the interstices

interstices of the rubble makes it grow firmer, whereas the constant action of the current upon the weakest part of a bulwark or jetty, viz. the termination thereof, puts it in a constant state of waste and decay.

By the application of rubble we have stopped the most formidable breaches where the river has had its course through, by means thereof we secure our banks and the aprons of our locks and dams upon the river *Calder*, over which last the water in time of floods has much greater rapidity than the natural current of the *Tay* possibly can have in the neighbourhood of *Pertb*; in short, we make use of it in all our defences upon the *Calder*, and have never found it to fail. I know it will readily be urged, that the *Tay* being a larger river than the *Calder*, that what will do upon the one, may not do upon the other; it is true, that the *Tay* is a wider river, but it does not appear to be more rapid, that depending chiefly upon the fall, which in the *Calder* is above 8 feet per mile for above 20 miles together, that we are concerned with it, nor does it appear that the *Tay* in time of floods rises to a greater height above its common surface. Hence I infer that the action of the *Calder* upon its banks is as great as that of the *Tay* upon its banks, because the quantity of this action depends upon the height and rapidity of the water acting immediately against them, and not upon that which passes by at a distance from them, so that the width of the river is totally out of the question.

In general I would advise my Lord KINNOUL to be as sparing of these kinds of works as may be; for without a great deal of land be got or saved by a moderate quantity of work, though the method I have chalked out is the plainest, easiest, most durable, and cheapest of any thing I know, where stone can be procured at a moderate expence, yet that land would come very dear that would require covering with rubble.

Perhaps it may be suggested that danger may arise from letting the great bulwark go to ruin; for when in that state, if an inconvenience should happen to arise, it would be much more expence to repair, than to keep it in repair. But this I apprehend to be quite otherwise; for a mass of rubble thrown promiscuously together, upon the ruins of the present bulwark, will be more lasting than the present one can be with its present materials and form, and can always be repaired by addition.

Upon the whole, it appears to me, that the greatest damage done, or likely to be done, to my Lord KINNOUL's estate at this place, arises from currents of water topping the banks of the *Ammon*, and running over the surface with great rapidity, thereby taking away the earth, wear gullies, and leaving tracts of barren gravel in its room,

which will be the most easily prevented by embanking the *Ammon* as before described, and stopping the mouth of any such gullies as appear to lead the waters upon the land; yet notwithstanding this will not prevent the back water from returning up the flades from below, and standing upon the land to the same level as the *Tay* at the places of communication; however, the water there being in a manner stagnant, the ravage above mentioned will be prevented; but a total prevention of the floods from coming upon the lands can no otherwise be effected, but by embanking the whole round, both against the *Ammon* and the *Tay*, so as to be flood proof against the greatest extremes, with a proper sluice to let out the down-fall and soakage waters when the floods are over; and this, though I look upon it as a practicable work, yet the difference of rents upon the quantity of grounds concerned, does not seem to encourage an undertaking so considerable.

Having mentioned the expediency of banking against the *Ammon*, it may be understood I looked upon the *Ammon* waters to be the sole cause of the overflowings already mentioned: but the case appears to me thus; when the *Tay* is flooded, it would revert upon the channel of the *Ammon* to the same level, though no current was to come down the *Ammon* at all; and were the banks of the *Ammon* lower than those of the *Tay*, (as they really are about *Ammon Bridge*) the *Tay* would run up the *Ammon*, and first and most strongly run over at the lowest places, viz. near *Ammon Bridge*; but if at the same time that there is a flood in the *Tay*, there is one in the *Ammon* also, as must often happen to be the case, the current of the *Ammon* being stopped by the *Tay*, the *Ammon* must then be forced to rise to a greater height, till it can over-ride the *Tay*'s water, and for that cause rising to a greater height, will the more plentifully overflow its banks; but was the *Tay* low while the *Ammon* was in a flood, I don't apprehend much mischief would ensue from the *Ammon* alone.

With respect to *Bussey Mill*, I find that with the quantity of water issuing from the boot at the time I saw it, there is a power, when well applied and the machine rightly managed and used, of grinding a *Winchester* quarter of wheat per hour, and that such an erection, if done here, would cost from 4 to 500*l*.

Austhorpe, 13th Dec. 1763.

J. SMEATON.

RIVER DEVON NAVIGATION.

Some Points relative to an intended Navigation upon the River *Devon*,
stated by Lord CATHCART, and answered by JOHN SMEATON.

Sir,

IF I rightly understand you in our late conversation, your opinion upon the points stated to you was as follows.

1st. That if the isthmus of *Long Cars*, betwixt *Alloa* and *Cambus*, were cut with a canal, the sides properly sloped and faced with rough stone, (as you may more particularly explain in the margin) and the present channel of the *Forth* allowed to remain as it does, such canal, the banks being of a height to contain the tide, would not endanger the adjacent lands by bringing more water that way than is intended., will have no occasion for flood-gates, and will be an effectual improvement to the navigation, by avoiding the *Thraik* shallows, and other impediments..

My Lord,

THE points stated by your lordship contain the substance of what passed betwixt your lordship and me in conversation, therefore, to avoid repetition, shall note in the margin what I have occasion to enlarge upon, or wherein your Lordship seems to have misunderstood me.

1st. In this particular I understood your Lordship that the *Thraik* shallow is a flat, shallow at low water, not of such an height as to pen the water above it, but merely an impediment to navigation, through want of depth. This being the case, a canal cut through the isthmus will have no other effect than here described, and the sides of the canal being sloped from the proportion of 2 to 1, to 1 to 1, as the soil may happen to be from a loose earth or gravel to a firm clay, and being covered with rubble quarry stones (suppose one foot thick), so as to make a compleat cover, this will not only defend the bank from the action of the current, but of the waves occasioned by the wind; but in case the shoal abovementioned makes a considerable pen; so as to determine the current much more strongly through this new canal than through the course of the river, it will be necessary to defend.

defend the *bottom also* with stones, to prevent the action of the water from deepening the same, and thereby sapping the foundation of the stone facing, and in consequence bringing down the banks and widening the canal. In case the pen should be very considerable, it would be necessary to build a lock upon it; but the determination of this matter depends upon the length of the canal, and difference of level of the surface of the river at the head and tail thereof, taken at low water, when there is no fresh in the river, as also upon the quality of the ground forming the bottom.

2d. That if the river *Devon* was navigated by Sir JOHN ERSKINE, from the *Cobble Crook* to *Cambus*, by means of sluices on *Tilli Body Bridge*, that navigation may be better effected by the canal and lock proposed than it could have been by the sluices, and the ground through which the canal passes, viz. from *Minefrie Lint Mill Dam* to *Tilli Body Bridge*, being clay and perfectly level.

3d. That from *Cobble Crook* to *Sauchie*, there being only two small fords in the way, the navigation may be effected by one lock and dam at the lowest ford, in case it should not be found better to avoid the fords by cutting from deep water to deep water, and making a channel behind the fords; but that this expedient, which is the best, cannot take place if the present fords act as dams, and the new cuts

2d. There is no doubt but that locks are preferable to simple sluices.

3d. I beg leave to add, that if a dam is built upon the ford, or the upper ford be supposed to act as a dam, a canal with a lock upon it, brought down so as to drop into the river below the lower ford, it will also equally answer the end if found most easily practicable. Also, if instead of joining the deeps by cutting a channel behind the fords, the fords themselves be removed, or channels through them be made,

should have the effect of letting down the river, and creating other fords in parts where the upper part of the navigation is intended to go.

4th. That you recommended carrying the navigation by locks out of the river at *Old Sauchie*, and raising it into a canal, upon the level of the river above *Tilliscoutery Dam*, to be carried in the line and direction of Lord CATHCART's aqueduct, (till it falls under ground into the pipes where it crosses the *Devon*) and there to be carried in an aqueduct bridge over the river, and continued to the dam, and from thence to the foot of the *Rack Mill Dam*, where there must be locks to surmount the said dam, in case the navigation is carried on to *Vicar's Bridge*.

5th. That the level of the stretch from *Sauchie* to *Mellock* foot is proved by Lord CATHCART's aqueduct and the present state of the *Devon*, which is already navigable betwixt *Tilliscoutery Dam* and *Mellock*.

6th. That the rising of the river in times of flood, so as to overflow the aqueduct bridge, does not infer any danger, either to the bridge or adjacent lands.

made, this will also answer; but in this case, care must be taken to make the channels on such side where the principal tendency of the water is to act in floods, otherwise they will be liable to be thereby filled up again.

4th. This seems to be the method from what was described to me upon the plan; but as it is scarcely possible to form adequate notions without ocular inspection, much must be left to the judgement of him who executes, in respect to the choice of the ground.

5th. Certainly, supposing the said aqueduct to be carried upon a level.

6th. It must be supposed that the dimensions of the water-ways, breadth and depth taken together, under the aqueduct bridge, must be such as to vent the water as fast as it comes in at extremes of floods, and also the ice in winter, otherwise great damage may ensue both to the works and adjacent lands, unless a certain length of the side walls of the bridge that sustain

sustain the canal are very strongly capped with stone, and left lower than the rest, for the water to flow over like a dam; but this expedient I would not recommend to be used, if it can be possibly avoided. N. B. I don't at present remember why the passage of the river cannot be obtained by raising a dam in the river below the intended place of crossing.

7th. That, upon the whole, as thus represented to you, the navigation of the *Devon*, and the improvements of the navigation of that part of the *Forth*, between *Cambus* and *Alloa*, seems very practicable, and, from the nature of the levels, at a moderate expence, considering the length of the navigation.

7th. Agreed.

8th. That from your experience in navigation bills, and their consequences when passed into acts, it is your fixed opinion, that the execution can neither be answered for, nor depended upon, in the hands of trustees, and that the only safe and sure way is for the proprietors of coal within reach of *Devon*, and Mr. ABERCROMBIE, to be the undertakers, or for Lord CATHCART to be the undertaker, with a proviso in favour of the other coal proprietors and of Mr. ABERCROMBIE, in case they shall chuse to recede, and naming a number of Commissioners to be

8th. This I have enlarged upon in my letter from *Newcastle*; I have only to add, that in this case the adventurers should be fixed down to take a reasonable toll for coals from the other coal owners, who may not in their present situation chuse to be adventurers themselves, otherwise the proprietors of the navigation may chuse to lose those tolls altogether, to prevent the others from working their collieries, which would be a detriment to the public.

referred to, and to judge betwixt the undertakers and other proprietors in all questions that may arise now or hereafter, with respect to damages, &c. in consequence of this act, by which means the parties interested in the toll will attend to the execution; and as the toll never can be suffered by the undertakers to rise to the price of land carriage, the difference, whatever it is, is so much saved, and therefore a benefit to the public.

9th. I forgot to ask the dimensions and size of the boats proper for the carriage of coal, and how deep water they will require.

As also whether is a better method to land the coal from the canal on the pier, and load them from thence on board the ships, or to let the boats down into the river by locks, and put them on board directly from the lighters.

Your certifying the above to be your opinion, or marking on the margin where I have misunderstood you, with some explanation for the satisfaction of the other persons concerned in this bill, relative to the 1st, 6th, 7th, and 8th articles, with your

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9th. The size of the boats used for carrying coals is various in different places, and differ in size, shape, and draught of water, according to the convenience of the place; but I apprehend that such boats as are principally used in the *Yorkshire* rivers, will answer as well as any for such a navigation, as proposed by your Lordship, viz. 54 feet long, stem and stern post included, $13\frac{1}{2}$ feet wide, and 3 feet draught of water; those will carry from 20 to 30 tons, according as they are more light or heavy built.

If the ships were always ready to be loaded, when the boats brought down coals, it would certainly be the most advantageous to lay the boats alongside the ships; but when the ships are not ready, they must necessarily be landed upon some quay or wharf common to

both,

opinion upon the 9th, will very much oblige, Sir,

Your most obedient
humble servant,
CATHCART.

London, Feb. 11, 1765.

both, which I apprehend should be covered like the coal staiths at *Newcastle*. Whether the quantity that can be delivered alongside the ships, in proportion to what cannot, together with the advantage of an open communication of the canal with the *Forth*, for the conveyance of other goods and merchandize, will make it worth while to make the necessary lock, is a matter of convenience that can only be determined upon the place, by those well acquainted with the nature of the trade thereof.

The cases stated, considered with my answers thereupon, contain the opinion upon these matters of,

My Lord,

Your Lordship's
most humble servant,

J. SMEATON.

Austhorpe, 20th April, 1765.

QUERIES, &c. communicated by Lord CATHCART, relative to a navigation on the *Forth*, November 5, 1767.

BY the Report of Messrs. WATT and MORISON to the Board of Police, it appears,

That a navigation may be opened at a small expence from the valuable woods, lime and slate quarries of *Aberfoil* to the bridges of *Aberfoil* upon the *Forth*.

That it may be continued from thence to *Cardrofs*, by a lock below the ford of *Cardrofs*.

That it may be continued from thence to *Frew* by a lock below the ford of *Frew*.

That from thence the river is navigable to a rocky ford called *Craig Anet*, betwixt the *Bade* and *Drip Coble*, which is two feet higher than *Craigforth* mill-dam, which last is three feet higher than the cruives of *Craigforth*, which are four feet above the neap tides, in the lower part of the *Forth*.

That a dam of three feet should be added for the sake of deepening the water, as far up as the *Frew*, which water so raised would be 12 feet above the neap tide.

That a canal near a mile in length, from a point above the *Bade*, across level ground of a clay soil, with a lock of 12 feet fall, would compleat the navigation from *Aberfoil* to the tides-way at the new mill of *Craigforth*.

And that the navigation from thence downwards may be shortened about seven miles by four cuts, as expressed in the plan, below *Stirling Bridge*.

It appears by Mr. SMEATON's report to the proprietors of the *Devon* collieries,

That *Cambus*, with proper improvements, may be made a very convenient port for exporting sea coal, and for accommodating ships in that trade.

That the river *Devon* may be rendered navigable from *Mallock* foot to *Menstrie Lint* mill-dam, which space includes five collieries.

And that the navigation may be continued from *Menstrie Lint* mill-dam, to the tide-way in the *Forth* at *Cambus*.

Menstrie mill-dam is 12 feet above the neap tides, therefore on a level with the water above the three-feet dam at *Craig Anet*, in the *Forth*, projected by Mr. WATT.

Suppose $2\frac{1}{2}$ feet added to the height of each dam, the water in the *Forth* above *Craig Ane*, and in the dam above the *Lint* mill-dam, will still be equal, and $14\frac{1}{2}$ feet higher than the neap tides.

The ground is clay, and very level from *Menstrie Lint* mill-dam to a point betwixt the bridge at *Stirling* and the new mill at *Craigforth*, where the banks on both sides are pretty high; and Mr. WATT's canal may be brought, upon very favourable ground, to a point opposite to it.

Suppose an aqueduct bridge of a proper dimension, erected across the *Forth*, betwixt these two points, (the distance being 300 feet) there will be dead water from *Frew* to the *Lint* mill-dam, by which the upper part of the *Forth* will have an easy, short, and open access to the *Devon* collieries, and also have an opportunity of dropping into the tides-way at *Cambus*, by locks of $14\frac{1}{2}$ feet fall, the advantage of which, considering how much lime-stone, slates, wood, &c. must come down, and how much coal must go up the *Forth*, including the consumption of the town of *Stirling*, and the inhabitants of those parts of the country that come through *Dumblain*; and that the lock at *Craigforth* new mill, and a great length of navigation, and the loss of time in waiting for the tide, will be saved, is extremely obvious.

The only circumstance of doubt is the practicability and expence of the aqueduct bridge, the length being 300 feet, and the bottom of the river clay, and far above rock; if it is executed in stone, the number of piers which it will require, as the level will admit of so small a rise for the arches, and the foundation which must be piled, it is apprehended must render the expence enormous. If it is executed in wood, upon the plan of *Julius Caesar's* bridge, which is well-adapted to resist ice, or other floating bodies, or upon any better more modern construction, it is apprehended it would come much cheaper, would stand against the force of the stream, and of the ice in winter, and would not be affected by the land floods, which cannot rise to the sole of the aqueduct, but must be liable to the expence of repairs to which a stone bridge would not be subject.

Mr. SMEATON, who is acquainted with the nature of the rivers and country adjacent in question, and skilled in every expedient that may facilitate the junction of the two level canals, by an aqueduct, is desired to say,

1st. Which of the two plans, the aqueduct bridge and canal to join it to the *Devon* at the *Lint* mill-dam, or the lock at *Craigforth* new mill, seems, upon the face of them, the most eligible for the inhabitants of the upper part of the *Forth*?

2d. If the aqueduct plan seems the most eligible, what *data* will be necessary to furnish Mr. SMEATON with, to enable him, at his leisure, to make out a design for the bridge.

3d. Does Mr. SMEATON think that the boats recommended for the *Devon*, drawing three feet water, of $13\frac{1}{2}$ feet width, and 56 feet long, will answer all the purposes of the *Forth* boats, or would it not be proper to allow for a foot more draught of water, in order that their flates, &c. may be carried coastways, and that the locks and canals be for that purpose proportionably deepened?

4thly. Suppose the aqueduct bridge rejected, and the lock at *Craigforth Mill* adopted, will it not be expedient to make the four cuts in the *Forth*, as marked in the plan; and if any, but not all, which of them?

5th. The ditches from *Tillibodie Bridge* to *Manner Pow* are from 8 to 10 feet deep, and about 12 feet wide, and are on a level with the *Devon*, at *Tillibodie Bridge*, and with Sir JOHN ERSKINE's canal at *Cambus*, would it not be right to build a lock at *Manner Pow*, and to enlarge these ditches, that *Upper Forth* boats might get, by that tract, to the collieries, whereby upwards of 6 miles navigation would be saved?

ANSWER to five Queries concerning the improvement of the Navigation of the River *Forth* from the River *Devon* upwards, communicated by the Right Honourable the Earl of CATHCART, in a Letter of November 11th, 1767, to JOHN SMEATON.

1st. IF the communication of the *Devon* collieries with the upper *Forth* was the sole object in view, then the long canal, from above *Stirling* to the *Lint Mill Dam*, upon the *Devon*, seems very well adapted for that purpose, and in that case would merit serious consideration, how far the aqueduct bridge, over the *Forth* (which indeed seems the only difficulty) might not be (under the specified circumstance of elevation) an executable scheme; but if the expence and difficulties of executing such a bridge there, as well as the expences of land, cutting bridges, and other contingencies attending the proposed canal

canal be considered, and that at last it will not save above 5 miles * of distance, though none of the loops below *Stirling* are supposed to be cut; if, on the other hand, the advantages arising from a free and open navigation to all parts of the *Forth* below, for all kinds of traffick, be put in the other scale, I cannot hesitate to say, the advantages being considered with the expence, and probability of trade, that it appears to me, on my present view of the proposition, more eligible to lock down into the *Forth*, near *Craigforth* new mill, and below that to keep the river.

2d. This is answered by the first.

3d. If the vessels were made of greater draught of water than 3 feet, and wider than 13 feet 6 inches, they would undoubtedly be more safe in navigating the broad part of the *Forth*, and coasting, and could venture, and keep out in worse weather; but such vessels, as described for the *Devon*, not only go in the narrow rivers in *Yorkshire*, &c. and down to *Hull*, but even go out to sea, and cross the *Lincolnshire* washes to *Spalding* for corn, to be carried in the same vessel to *Leeds*, *Wakefield*, and *Halifax*; but as it is obvious that if the bulk of the vessel is increased, it will occasion greater expences in executing the locks, cuts, canals, &c. it may therefore be worth while to consider, with the degree of trade that is probable, whether it may not be eligible to save a capital that must thereby be expended by changing: for though the vessels above-mentioned can, and do go as before set forth, yet the bulk of trade is carried on by changing vessels at *Armine*, that is as soon as the river is capable of receiving sloops of 50 and 60 tons.

4th. The most important object in making artificial navigations, is to avoid dead stoppages by want of water, &c. In many principal navigations in England, vessels are frequently stopped in dry seasons for one, two and three days at a time, sometimes for a week together. Now, if they had a certainty of going at a particular time of tide, twice in 24 hours, they could suit their times accordingly, and would be content to go several miles about, if they had a certain passage, rather than lie still so long together; for this reason, cuts are seldom made merely and simply for shortening distances; and though in the district under consideration the river is remarkably crooked, yet, as the rest of it, both above and below, is but little better, it may deserve a serious consideration whether it is worth while to make any of the cuts proposed below *Stirling*; for as, according to the plan I have, the difference of distance is but about 5 miles, with the cuts and without them, the Engineers would therefore do well to consider, from actual admea-

* The distance up the *Devon* being taken into the account.

measurements of the respective lengths, and levels taken, how deep, how wide at bottom and top, each cut will be required, in order that they may be materially more passable than the present fords; and to effect that, how deep they will be required to be dug below low water, what land must be cut and covered; these things being ascertained, and proper estimates made from the price and quantity of excavation, the price and quantity of land, the charge of pumping water while the digging is going on under level, and the damages that may be done by the river's breaking in while the works are going on in that situation, also the charge of making dams to turn the water from the cuts, or if none, the time lost in getting the tracking horses across the old loops; I say all these things considered, and estimates formed from particulars, will soon direct you, whether from the probable quantity of trade, the expence of any, all, or some of these cuts, will be balanced by the time in the passage respectively saved. The two upper ones seem the most advantageous, the rest in order as they are lower; but it will be right to have a power in the Act to make any of these cuts; that after the necessary canals, locks, &c. are made, if it shall appear from the quantity of trade, and the goodness of the funds, that the thing is eligible, there ought to be a power of doing it without a fresh application.

5th. The expediency of this step consists in the facility in doing it, because the advantage will wholly consist in the trade with the *Devon*; for it will not be worth while for a vessel at the mouth of the *Devon*, and going up the *Forth*, to make use of this passage, because, in going round the great loop, she will be thrown about only $1\frac{1}{2}$ mile more than the artificial passage, in which latter she would have to pass two locks.

It is to be observed, that by a double entry into *Devon* the leakage will be double; and if made use of as a passage up and down the *Forth*, each vessel will expend two lockfulls, except in cases of meetings.

Austhorpe, November 21, 1767.

J. SMEATON.

Lord CATHCART'S Queries relative to the River *Devon*.

MR. SMEATON to consider the *Cambus*, and the river below the *Cambus*, and to give his opinion, whether the *Cambus* can be made a proper port of exportation for great coals, and if it can, by what means, and at what expence.

Objections.

Objections. Want of depth of water, expence of making a new port, loss of time to ship-masters to come so much further; danger from ice in winter.

If either impracticable, or too expensive, Mr. SMEATON will consider whether the coals cannot be carried in boats down the *Devon* and *Forth* to *Alloa*, and there shipped for exportation.

Objections. Coals carried down to *Alloa* by water cannot be folded there without great expence, but must be loaded from the lighters, which ship-masters object to, for reasons perhaps frivolous, but will best be collected from themselves, and judged of by Mr. SMEATON.

If coals brought down the *Devon* can be exported either from the port of *Alloa*, or of *Cambus*, Mr. SMEATON will then consider the best method of rendering the *Devon* navigable, from *Mellock* foot to the *Forth*, either by a canal, or in the bed of the river, or partly by one, partly by the other, calculating the expence of the whole, and specifying the dimensions of boats, what they are to carry, and how to be drawn.

The size and dimension of boats will depend upon the use intended; if they are not to be let into the *Forth*, they may be very long, very narrow, and very shallow, which will reduce the expence of the canal. If intended to go down to *Alloa*, or up the *Forth*, they will not admit of the same construction.

N. B. The possibility of going up the *Forth* by water from the collieries would be a great conveniency, because were the navigation opened above *Stirling Bridge* by locks at *Craigforth*, *Frew*, and *Cardrofs*, all the country on each side the *Forth* might, as well as the town of *Stirling*, be supplied by water-borne coals from the *Devon* collieries.

If Mr. SMEATON finds any species of navigation practicable and adviseable, he will favour the coal masters with his ideas of the proper Act of Parliament to be petitioned for; and of the places, proportion, and manner of collecting tolls, and manner of shipping the coals either from boats or quays; and if he will undertake, or recommend an undertaker for the whole, or the locks only, and on what terms.

To this may be added a remark of Messrs. MACKELL and WATT lately made; that is, that a canal may be carried upon a dead level the whole way from *Tillicoultry* to a point opposite to the schoolmaster's house at *Alloa*, following the foot of the rising grounds the

the whole way, that it will be about 30 feet higher than the sea, and may either be carried betwixt banks across the flat grounds, which is not far, to the shore, otherwise the flat ground may be cut to bring the *Forth* up to the low grounds.

This would save locks and waste of water as far as *Tillicoultry*, and might be joined by a canal from *Mellock Foot*, the level of which would be a very little higher, and might require a lock.

Levels.			Feet.	Inches.
From <i>Forth</i> to <i>Sauchie</i> ,	-	-	18	10
From <i>Sauchie</i> to <i>Mellock</i> ,	-	-	19	6
From <i>Mellock</i> to <i>Vicar's Bridge</i> ,	-	-	39	6
			<hr/>	<hr/>
			77	10
			<hr/>	<hr/>

The REPORT of JOHN SMEATON, Engineer, concerning the practicability and expence of making navigable the River *Devon*, in the county of *Gloucestershire*, from *Millock Fort* to the River *Forth*.

THE river *Devon* falls into the river *Forth* about $2\frac{1}{2}$ miles above, or to the west of *Alloa*, but according to the turns of the navigation, up *Forth*, about $3\frac{1}{2}$ miles. There are several valuable collieries upon the slope of the hills that decline towards the river *Devon*, the coals of which are now carried to *Alloa* over land, in order to be put there on board vessels capable of carrying them to all parts where wanted. The more easy carriage therefore of those coals; from the collieries to the shipping is, as I apprehend, the principal object of the present proposed navigation.

At the mouth of the *Devon* the extreme spring tides are said to rise 20 feet perpendicular, and at such tides the water flows one foot higher than the top of *Cambus Quay*, which is an old quay, at which formerly coals were shipped, about a furlong within the mouth of the *Devon*. The common neap tides are said to rise within five feet of the top of the said quay, and that then there is 12 feet water in the river *Devon* opposite the said quay. When I was there, the morning of the 20th of November, 1766, being the fourth day after the full moon, it appeared that the mark left by the last tide was as high as any that had been that spring, and what might be called an ordinary spring tide: this I found had been within 1 foot of the top of the said quay; and consequently, being 4 feet higher than the ordinary neap tide mark, made 16 feet water in the river opposite the quay. At the time I was there it was almost low water in the *Forth*, and then the current of the *Devon* ran with a considerable declivity towards the *Forth*, having a fall of not less than 2 feet.

The declivity of the bottom of the river from *Cambus Quay* to the *Forth* appears pretty regular; the bottom opposite to and above the quay seems to be mud, intermixed with large tumbling stones; these stones being removed, the mud would wash away, so that I look upon it as very practicable to make 2 feet more water at *Cambus Quay* than at present, that is, to make 14 feet at ordinary neaps, and 18 feet at common spring tides.

If more water than the above should be requisite, I should look upon it as more eligible to dig out a new channel and harbour from the *Forth*, which may be done on the west

west side of the *Devon*, the ground there being low and flat, and gently rising from low water mark; this work may, therefore, be done at a moderate expence in proportion to such a work, but yet must, in digging, walling, &c. amount to a considerable sum, more than would be necessary to rebuild and enlarge the old quay and deepen the river, as aforesaid.

To the safety of the place there seems to me no material objection; for as to ice in winter, it cannot do much harm, as it must be much broken in passing the bridges and dams before it gets to the *Cambus*. It is no peculiarity of the river *Devon*, and is the case, more or less, with every sea port which has the advantage of being scoured by a fresh water river, which is in itself very desirable.

In going up the *Forth* from *Allea* to the *Cambus*, the navigable channel of the river makes one large half moon, but as it is in general sufficiently spacious for vessels to turn, this case also differs little from what is common in other tide rivers; it will undoubtedly be some hindrance to vessels going $3\frac{1}{2}$ miles further up, but as this can hardly ever be attended with more than one tide loss of time, and often without the loss of a tide, it may as well be said that the coals ought be carried down to *Kincardine Road*, to prevent the possibility of the loss of a tide in going to *Allea*. The principal impediment in getting betwixt *Allea* and *Cambus*, for vessels of burthen, is occasioned by a shoal called the *Frašk*; and this arises not so much from want of depth of water, as from the narrowness of the channel; for in sounding the river at low water the day above specified, we sounded in the channel over the *Frašk* no less than 5 feet, which, though the shallowest place between *Allea* and the *Cambus*, seems yet a very sufficient passage, at all proper times of tide, for vessels bound to an harbour, where they could lay dry at low water the same tide.

This shoal seems to consist of a ledge of stones which lays almost across the river from S. W. to N. E. confining the channel close in with the point, which is an unusual situation for the channel, but arises from the greater softness of the ground in that part where the channel is. As this shoal is short, according to the direction of the channel, it seems very practicable to remove the stones, so as to increase the same in width. There is at present a sufficiency of width, when proper beacons are set, for the passage of vessels right upon and down, but not of these turning to windward.

This shoal may also be avoided by cutting through the neck of land; but if the great depth that such cut will be required, (the ground seeming there 18 or 20 feet higher

higher than low water) the depth to which it must be carried below low water, and the great width that it must have in the bottom, to make it a more eligible passage than by the *Frašk*, be considered, I believe it will appear that the canal may be extended to *Alloa* for almost as little, if not less expence. It perhaps may be expected that if the cut is made narrow, and down to low water, that in time it will wear itself wider and deeper, and so indeed it may, but whether this will happen in the compass of seven years or twenty, or whether it will ever happen, so as to be (as already said) a more eligible passage than the *Frašk*, I think is out of the power of any man to say with certainty; for it is to be observed, that till it becomes much wider than the *Frašk* and equally deep, it will be more difficult to turn to windward through it on account of its greater length.

As the natural declivity of the river from head to tail of this supposed cut is very little, unless a dam was put across the main river to force the current through the cut with some considerable velocity, the water could not in its natural state be expected to operate very speedily; and as the width of the river through its several channels in this place is very considerable, such dam would be very expensive, would obstruct the navigation while the new channel was wearing larger, and by depositing of the matter and diverting the present channel, there is no saying but that after all a shoal might be formed in some place where now there is none, as troublesome as that we would mean to avoid; for these reasons I cannot, in my present view of the matter, recommend this division of the river from its present channel.

With respect to the dimensions of the canals, cut out from the course of the river *Devon*, they depend upon the kind and sort of vessels to be employed, and the sort of vessels will again be determined by the uses to which they are to be applied.

If the vessels are to be employed merely in bringing down coals from the collieries to the quay, where the ships load without going into the *Forth*, vessels long, narrow, and shallow, may be used with advantage, but if intended to go up and down the *Forth*, they will require a different construction.

It seems to me, that if the navigation be limited to the canal only, without going into the *Forth*, it will be attended with many inconveniencies, but that it will be of more general use, if capable of containing vessels capable of going up and down the *Forth*, as well as of navigating the canal; for by this means vessels may be loaded at the *Canal Quay*, or at *Alloa*, as may be most suitable to the sea vessels to be loaded,

or they may be carried up the *Forth* to *Stirling*, and up to *Gartmure*, in case the navigation above *Stirling* is completed, which if confined to the winding course of the *Forth* may be done at a very moderate expence, as I have formerly shewn in my report on the proposed canal from *Forth* to *Clyde*.

The very extensive trade up the river *Aire* and *Calder* in *Yorkshire*, which passes under *Ferry Bridge*, and of which coals is the principal article, is carried on in vessels of 56 feet long, stem and stern, 13 feet 6 inches wide, and drawing 3 feet water at a medium; in very dry times in summer they load 6 inches less, and in winter 6 inches more. These vessels at 3 feet draught of water carry, by reputation, from 20 to 25 tons, but of neat dead weight 28 tons; they are generally drawn by one horse, and make way nearly two miles an hour, stoppage at the locks included; though sometimes, for the sake of expedition, and when there are freshes in the river, and the vessels going against stream, they make use of two.

These vessels not only navigate in the narrow rivers, but go round into the *Trent* to *Gainsborough* and *Newark*, and frequently down the *Humber* to *Hull*. This sort of vessel, I apprehend, by the same rule, would not only go down to *Alloa*, and deliver their cargoes there on board ships, but would occasionally go into the *Carron*, and through the great canal, in case the same should take effect.

By this means, if a large ship meets with contrary winds, or comes in at such a time as to expect being neaped at the *Cambus*, she may be loaded at *Alloa* from the boats, in the same manner as all the ships at *Newcastle* and *Sunderland* are loaded from the keels there, which carry 21 tons each; on the other hand, when there are no ships that want loading at *Alloa*, or they happen to be brought down faster, then they are shipped at the *Cambus*, or sent away in the same bottoms to other places up or down the *Forth*, they then will be deposited in the coal-yard at *Cambus*, ready for the vessels that come up thither for a loading.

The dimensions of the *Calder* cuts for the vessels above described were, 16 feet bottom, the sides sloped 5 feet for 3 feet of perpendicular, and carrying $3\frac{1}{2}$ feet of water; now, in carrying canals upon a dead level on the decline of hills, the ground is seldom so free from irregularities, but that it requires extra cutting in some places, and extra banking in others, which, as it would be impossible to determine exactly before the execution, as every variation, though but for a few yards, would vary the dimensions, must be allowed for according to the judgment of the artist; to make allowance therefore for the common

common inequalities of ground in the present case, I compute upon a cut of 6 feet deep, that is, supposing the water $2\frac{1}{2}$ feet within soil; not that I expect it to be so in the general; but as in many places the extra cutting will be considerably more, and the deficiencies remain to be made good by so much labour, I make that supposition in order to come at the mean value.

Upon these general dimensions I have computed the expence, upon a supposition of an entire canal, except where it is proposed to come into the river, for the sake of crossing the same, to get the eligible ground, which amounts to the sum of 9357*l*.

2d. Supposing the river to be made use of in the general from *Tillibodie Bridge* to *Saucie* new engine, with short cuts to take off loops and place the locks, in this case, though far less apparent work, yet as the disadvantage of placing the locks, as well as of constructing them, and laying their foundation below the level of the river, as it will require a lock more, a greater price for each lock, a greater depth of cut, and, on account of greater depth, as well as drainage of water, a greater price per yard of digging; I say, all those being allowed and computed, as in my judgment they ought to be according to the following estimate thereof, this will make the whole stretch from *Tillibodie Bridge* to the elbow of the river above *Saucie* old engine, near *Tillicoultry Burnfoot*, to amount to 4793*l*. whereas if done by canal, according to the first supposition, it will cost 5183*l*. the difference being 390*l*. in favour of the river navigation; but if it be considered, that following the river increases the length near $1\frac{1}{2}$ mile in $6\frac{1}{2}$ miles, and that the works themselves will be perpetually in greater hazard from floods, and need more repair, this difference does not appear to be worth the saving.

As I observed the ground very capable thereof, I have computed the value of two miles of canal, which I suppose, if turned southwards a little below *Menstrie Bridge*, will carry it to *Alloa*: this is done upon a supposition of 40*l*. an acre for the land, which I apprehend to be very valuable in that district, the rest of the dimensions and prices as per first supposition; this will cost the sum of 2408*l*. This supposes a lock into *Forth*, but being nearly the same as that at *Cambus*, the only addition is in the canal.

Respecting the prices of land, I would be understood once for all, that I don't in these estimates by any means propose to fix a value upon it, as being an affair quite out of my province; but when different schemes are to be compared together, some value must be affixed to each of the component parts, in order to bring them to a comparison; for the cuts upon the valley of the *Dever* I suppose 20*l*. per acre average price, though

I am

I am very sensible that some of the grounds through which the cuts will pass, are more than ten times the value that others are : but as I apprehend the whole of the supposed cut from near *Menstrie Bridge* to *Alloa*, will pass through grounds as valuable as the best in the *Devon* valley, the comparison would in no respect hold, unless an addition was made to those supposed for the *Alloa* cut.

I now come to the article of water, and for this purpose particularly observed the new mill at *Tillibodie*, which is situated upon the river *Devon*, and enjoys the whole stream thereof; its water is penned by the same dam, from whence the cut is proposed to be taken to *Cambus Quay*. This mill, when going at its common rate, requires the sluice to be drawn up 11 inches upon a breadth of 3 feet, there being then a depth of water upon the sole of 25 inches.

Having hence computed the quantity of water expended when the mill was going at this rate, it comes out to be 1180 cube feet per minute. A lock required to carry vessels of the size above specified, will require to be 62 feet long, and 14 feet wide, whose area upon each foot in depth will be 868 feet; and supposing a lock to be of 6 feet pen, this will require 5206 cube feet to fill it, and the passage of each boat will require this quantity, unless two boats should meet together at a lock, one going up, and the other down, they then will both pass with one lock-full; but as this does not always happen, I generally reckon upon a lock-full to each boat, the savings of water upon the afore-said circumstance going in aid of the loss of water at the locks by leakage. Now the contents of a lock 5206 cube feet, being divided by 1180 cube feet expended at *Tillibodie Mill* per minute, gives $4\frac{1}{3}$ minutes for the time in which the said mill expends a lock-full of water of 6 feet high.

Again, if we suppose 10 boats to pass in a day, that is, 5 up and 5 down, we may very well suppose that out of these 2 may meet at or within sight of the lock; and if so, a lock-full of water will be saved, which I esteem equal to the daily leakage of a well-made lock; but however, to make an ample allowance for loss of water, not only by leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-full per day; the total expenditure will then be 14 locks-full, which will be equivalent to 61.6 minutes, or 1^h 1' 42"; and this will be the time that *Tillibodie* new mill singly, and the two mills at the *Cambus* conjointly, will lose in 24 hours in the driest season; for at all other times, when the water runs waste over the dams, the navigation will not lessen the time of the mills working.

By information of the miller, there is in summer scarcely half the above quantity of water in dry seasons, that is, they can scarcely go at that rate above 12 hours in 24; hence the navigation, circumstanced as beforementioned, will consume about $\frac{1}{11}$ part of the water that now goes to the mills in dry seasons; or, dividing the whole quantity into 11 parts, the mills will get 10 and the navigation 1; but, upon my view, it appeared, that *Tillibodie* new dam was considerably leaky, insomuch that it is probable that in dry times as much water goes through the dam as goes to the mill; this will be the case if the leakage is only half the mill stream when working; for one being constant, and the going but for half time, they will be equivalent to each other; but, as it may be necessary to make some alterations in the dam of *Tillibodie* new mill, if this is rendered water-tight at the expence of the navigation, this mill will be a gainer and not a loser by the navigation. The *Cambus* mills, however, which are situated upon the same river, and take their water from the new mill of *Tillibodie*, and receive also the leakage from that dam, will not be compensated by that alteration; but as both the mills at *Cambus* work from one head of water, the loss to them both will be no greater than was estimated for *Tillibodie* mill singly; but the loss to neither of those sets of mills will take place, as to the lockage, except for such vessels as go down into the *Firth*; for all such vessels as deliver their cargo into the yard at the *Cambus* for shipping, which may be expected to be far the greatest part, will expend no more water from *Tillibodie* or *Cambus* mills.

It is true that, according to the different states of the tide, a perpendicular height might be wanted greater than six feet; but as it will be often less, I suppose the one may nearly balance the other.

It would render the affair of the mills intirely free from compensations if a stream could be turned into the *Devon*, that now goes into some other river, equivalent to what will supply the navigation, which, from my view in passing through the country near the head of the *Devon*, does not seem difficult to do.

However, upon the whole, it appears, that even in an extended view, the quantity of water that will be used by the navigation will bear but a small proportion to the currency of the river *Devon*, even in the driest seasons; and as a ground-work for a compensation, in case an equivalent quantity of water cannot be brought into the *Devon*, it appears that for every 5206 cube feet of water that is drawn out of each head, at such times when the respective mills can use the whole, a sum equal in value to $4\frac{2}{3}$ minutes work

work of such respective mills will be payable to the tenant or occupier of such mill or mills, he continuing to pay the same rent as before.

Now, exclusive of *Sauchie* engine, which will be proportionably affected with the rest, there are only three heads of water that will be affected, viz. the *Cambus* mills, which are corn-mills; *Tillibodie* new mill, which is also a corn-mill; and the mill above *Tillibodie Bridge*, which is a lint-mill; which, in proportion to the value of its time, will be affected in much about the same manner.

I make no account of foakage, because this, after the canals are seasoned, will be very trifling, and the greatest part will return into the river above the principal mills.

Austhorpe, September 14, 1767.

J. SMEATON.

P. S. In regard to the scheme that has occurred to Messrs. MACKELL and WATT, since I was upon the place, of carrying a canal upon a dead level from *Tillicoultry* to a point opposite the schoolmaster's house at *Alloa*, following the foot of the rising grounds the whole way, and which will be about 30 feet higher than the sea, proposing to continue the same from thence between banks across the flat ground to the waterside (which is not far), or making a cut through the flat grounds to the dead level termination of the canal, which plan would save locks and waste of water, I can only say, that, from my view of the country, I believe such a project practicable; but, as I have neither plans nor sections of the course that it would take, I am in no capacity to judge of the expence.

It is obvious that this canal would be defective in not suffering the vessels to pass into the *Forth*, and that either the banking across the valley, which would be a considerable height, or digging across it, which would be a considerable depth, would be a considerable article of expence; and that in any view of the affair, if a communication with the *Forth* is dispensed with, a considerable saving may be made, but I apprehend not above 1-3d, between carrying vessels to navigate the *Forth*, as above specified, and those the most curtailed that can any ways answer in point of quantity.

J. S.

ESTIMATE for making a Navigation through the valley of the river *Devon* from the *Cambus* to *Mellock Glen Foot*, supposed chiefly by a canal.

	£.	s.	d.
To widening and deepening the old cut from the <i>Cambus</i> into <i>Tillibodie</i> new mill-dam, which, from the depth of the ground, I estimate as a new cut, the width at bottom being 16 feet, mean width at top 36 feet, mean depth 6 feet, at 3d. per yard, will come to 47l. 13s. 4d. per furlong, the length being 4½ furlongs, - - - - -	214	10	0
To 1 lock from the cut into the tideway, - - - - -	600	0	0
To 6,14 acres of land, if purchased at 20l. per acre, - - - - -	122	16	0
To 1 cart-bridge for communicating with the land cut, - - - - -	40	0	0
To repairing <i>Tillibodie</i> new mill-dam, so as to render the same more nearly water-tight, - - - - -	200	0	0
To extra cutting for passing-places, &c. - - - - -	27	0	0
To extra land for ditto, - - - - -	15	0	0
<i>From Cambus Quay to Tillibodie Bridge,</i> - - - - -	1219	6	0
To clearing up and deepening the river from <i>Tillibodie Dam</i> , through the bridge, to the tail of the next cut, - - - - -	50	0	0
To cutting 3 miles 1 furlong of entire cut, of the dimensions above specified, from <i>Tillibodie Bridge</i> to <i>Sauchie</i> new engine, that is, 25 furlongs, at 47l. 13s. 4d. - - - - -	1191	13	0
To 34,1 acre of land, if purchased at 20l. at a medium, - - - - -	682	0	0
To a road-bridge over the cut, answerable to <i>Menfrie Bridge</i> , with a stone arch, - - - - -	80	0	0
To three cart-bridges to preserve the roads and communications between lands, from the above to <i>Sauchie</i> new engine, - - - - -	120	0	0
To extra cutting for passing-places, &c. - - - - -	149	0	0
To extra land for ditto, - - - - -	85	0	0
To digging a cut from <i>Sauchie</i> new engine to the elbow of the river near <i>Tillicoultry Burn Foot</i> , being in length 1 mile or 8 furlongs, at 47l. 13s. 4d. per furlong, - - - - -	381	7	0
To 10,91 acres of land, at 20l. - - - - -	218	4	0
To 2 cart-bridges over this cut, - - - - -	80	0	0
To 3 locks upon this district, at 500l. each, - - - - -	1500	0	0
To extra cutting for passing-places, &c. - - - - -	48	0	0
To extra land for ditto, - - - - -	27	0	0
To extra expence in cutting through the rising ground at the <i>Coble Creek</i> , - - - - -	100	0	0
<i>From Tillibodie Bridge to the head of Sauchie Cut,</i> - - - - -	4712	4	0

	£.	s.	d.
To raising a dam to pen about 7 feet water in the elbow of the river next above <i>Sauchie</i> old engine, near the foot of <i>Tillicoultry Burn</i> , - - - - -	500	0	0
To embanking the flat ground adjacent to the river <i>Devon</i> , on the north side from the said dam upwards, so as to be flood-proof, supposing it, at a medium, to be $\frac{1}{2}$ of a mile in length, 6 feet height, 6 feet top, and 24 feet base, this will contain 4400 yards, ramming and fodding or turving included, at 4d. - - - - -	73	7	0
To $1\frac{1}{2}$ acres of land, that will be cut and covered by this work, - - - - -	30	0	0
To extra expence in securing the land near the foot of the dam, and in guarding the same from the effects of <i>Tillicoultry Burn</i> , suppose - - - - -	100	0	0
<hr/>			
Expence of continuing the navigation half a mile up the river <i>Devon</i> , from the head of the <i>Sauchie Cut</i> to the tail of the cut near the bridge of <i>Tillicoultry</i> , - - - - -	703	7	0
<hr/>			
To widening or making a new cut past the bridge of <i>Tillicoultry</i> , from the dam into the river below the tunnel wherein the engine water crosses the same, being in length 2 furlongs, at 47l. 13s. 4d. per furlong, - - - - -	95	7	0
The land cut and covered will contain 2,73 acres, which, at 20l. an acre, comes to - - - - -	54	12	0
To a lock upon the said cut, - - - - -	500	0	0
To a road-bridge over the said cut, answerable to <i>Tillicoultry Bridge</i> , - - - - -	80	0	0
<hr/>			
The cut, &c. to pass by <i>Tillicoultry Bridge</i> into <i>Tillicoultry Dam</i> , - - - - -	729	19	0
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To cutting across the flat grounds from the first elbow of the river above <i>Tillicoultry Dam</i> to <i>Mellock Glen Foot</i> , being in length $5\frac{1}{2}$ furlongs, at 47l. 13s. 4d. - - - - -	262	3	0
The land cut and covered 7,5 acres, at 20l. per acre, - - - - -	150	0	0
To a lock upon the said canal, - - - - -	500	0	0
Two cart-bridges for preserving communications, - - - - -	80	0	0
To extra cutting for passing-places, &c. - - - - -	33	0	0
To extra land for ditto, - - - - -	19	0	0
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To carrying the navigation from <i>Tillicoultry Dam</i> to <i>Mellock Glen Foot</i> , - - - - -	1044	3	0
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SUMMARY of the Estimate for making a Navigation through the valley of the river *Devon*, from the *Cambus* to *Mellock Foot*, supposed chiefly by canals.

From <i>Cambus Quay</i> to <i>Tillicoultry Bridge</i> , - - - - -	1219	6	0
From <i>Tillicoultry Bridge</i> to the head of <i>Sauchie Cut</i> , at the elbow of the river above the old engine at <i>Sauchie</i> , and near <i>Tillicoultry Burn Foot</i> , - - - - -	4712	4	0
From thence, through the river, to the foot of the cut that passes <i>Tillicoultry Bridge</i> , - - - - -	703	7	0
The cut to pass by <i>Tillicoultry Bridge</i> into <i>Tillicoultry Dam</i> , - - - - -	729	19	0
From <i>Tillicoultry Dam</i> to <i>Mellock Glen Foot</i> , - - - - -	1044	3	0
<hr/>			
Carried over	8408	19	0

	£.	s.	d.
Brought over	8408	19	0
To 6½ miles of towing-path, which, with towing-bridges, gates, stiles, back drains, &c. is supposed to cost, 15 l. per mile,	97	10	0
	8506	9	0
Add 10 per cent. for unforeseen accidents and expences not included in the foregoing estimate,	850	12	0
	9357	1	

ESTIMATE to shew the difference between keeping the river as much as possible from *Tillibodie Dam* to *Sauchie* new engine, and the entire canal before proposed.

To clearing up and deepening <i>Tillibodie Dam</i> , through <i>Tillibodie Bridge</i> , to the tail of the cut, as before,	50	0	0
To cutting from <i>Tillibodie Bridge</i> into the <i>Lint Mill Dam</i> , being in length 4 furlongs, and which passing through deeper grounds than if carried upon a dead level, may be supposed 7 feet mean depth, which, with bottom and slopes as before, will contain 18164 yards, and which being deeper, and partly under level of the river, so as to require artificial drainage, I reckon at 4 d. per yard,	319	8	0
The ground cut and covered will be, at a medium, 100 feet wide, and therefore 4 furlongs will contain 6,06 acres, which, at 20 l. an acre, comes to	121	4	0
A lock upon ditto requiring drainage, and to be built higher than if upon a dead cut,	550	0	0
A cart-bridge over the cut for communication,	40	0	0
The work to pass the <i>Lint Mill</i> above <i>Tillibodie Bridge</i> ,	1080	12	0
To making a cut at the letter A, of 1 furlong of dimensions, as the former, will contain 4791 yards, at 4 d.	79	17	0
The cut and cover will contain 1,51 acres, which, at 20 l. comes to	30	2	0
A lock upon the cut as before,	550	0	0
A cart-bridge over the lock for communication to the island,	15	0	0
A dam to pen the water,	300	0	0
Cut, &c. at the letter A,	974	19	0
To making a similar work at B, which will carry the navigation to <i>Sauchie</i> new engine,	974	19	0
To 1 mile of cut, from <i>Sauchie</i> new engine to the elbow of the river near <i>Tillicoultry Burn Foot</i> , as per former estimate,	381	7	0
The land for ditto, as before,	218	4	0
To two cart-bridges, as before,	80	0	0
To a lock from the cut into the river,	550	0	0
To extra cutting for passing-places, &c. as before,	48	0	0
To extra land for ditto, as before,	27	0	0
Cut from <i>Sauchie</i> new engine to <i>Tillicoultry Burn Foot</i> ,	1304	11	0

SUMMARY

SUMMARY of the foregoing estimate.

	£.	s.	d.
Cut from <i>Tillibodie Bridge</i> into <i>Lint Mill Dam</i> ,	-	-	-
Cut, &c. at the letter A,	-	1080	12
Ditto, at B,	-	974	19
Cut from <i>Sauchie</i> new engine to <i>Tillicoultry Burn Foot</i> ,	-	974	19
Increase of hawling track $1\frac{1}{2}$ mile, at 15 <i>l.</i>	-	1304	11
	-	22	10
From <i>Tillibodie Dam</i> to <i>Sauchie Cut</i> , by keeping as much as possible the course of the river,	4357	11	0
Contingencies, at 10 per cent.	-	435	14
		4793	5
By an entire canal, as before,	£. 4712	4	0
Contingencies, at 10 per cent.	-	471	4
		5183	8
Difference of expence in favour of the river navigation,	-	390	3

ESTIMATE for continuing the navigation, by Canal, to or near *Alloa*.

If, instead of dropping the cut into the river just above *Tillibodie Bridge*, the level be preserved from the *Coble Crook*, and turned from near *Menstrie Bridge* towards *Alloa*, the increase of distance, according to plan, will be about 2 miles.

	£.	s.	d.
To 2 miles of cut, at 47 <i>l.</i> 13 <i>s.</i> 4 <i>d.</i>	-	762	13
To 21,82 acres of land, at 40 <i>l.</i> per acre,	-	872	16
Suppose 2 road-bridges, at 80 <i>l.</i>	-	160	0
To 4 cart-bridges, at 40 <i>l.</i>	-	160	0
To 2 miles of hawling track, at 15 <i>l.</i>	-	30	0
To extra cutting for passing-places, &c.	-	95	0
To extra land for ditto,	-	109	0
		2189	9
Ten per cent. for unforeseen events, &c.	-	219	0
Addition, to carry the cut to <i>Alloa</i> ,	-	2408	9

J. SMEATON.

Austhorpe, September 14, 1767.

Lord CATHCART'S Queries of the 11th of September, 1767.

To Mr. SMEATON, from Lord CATHCART, September 11, 1767.

IN winter the freshes and quantities of ice are so great, that it is difficult for ships to lie in the *Forth*; they are obliged in that season to shelter themselves in what is called the *Pow* of *Alloa*; they cannot go up to *Cambus*, nor can boats come down, which would prevent a constant intercourse between the *Devon* collieries and the ships in the *Forth*, supposing the navigation to be made partly in the *Devon*, and partly in cuts from *Tillicoultry* to *Cambus*, where it joins the *Forth*.

There is another method which would be certain and constant *, except when the canal was frozen, and is as follows: suppose Lord CATHCART'S aqueduct were to be widened to the proper size, from the pipes at *Tillicoultry* to the new engine at *Sauchie*, and from thence carried on upon the same level to the west end of the town of *Alloa*, it would finish upon a bank about 15 feet higher than the pier of *Alloa*, and about 300 yards distant from it; from this dead water canal a branch may be carried off, which will be very short, and which will terminate equally on a bank near the *Forth*, a little below the mouth of the *Devon*, from both which banks the coals may be conveyed in waggons to the sides of the ships at *Alloa*, or boats at *Cambus*, which come down the *Forth* from the upper parts of the river.

In this plan there are the following advantages :

There will be no locks ; there will be no waste of water, which will be particularly agreeable to some proprietors principally concerned.

The boats may be contracted in width and increased in length, and may be very flat, and consequently the canal much shallower and narrower, than if it were to carry boats fit to navigate the *Devon* or *Forth*.

And for these reasons it is supposed the navigation may be executed cheaper, and with more certainty than in any other method, and may in the same manner be carried up the

* Since writing, I have been informed, that the water drawn from the pits, with which the canal before mentioned would be filled, never freezes.

river, as far as proprietors please, on the north bank, although on the upper part there will be a necessity to have some locks, as it must be on a higher level than the under.

Query 1st. Were such a canal to be executed, what would be the proper dimensions of it, and of the boats, and what would be their burthen?

Query 2d. Would there be any difficulty in carrying such a canal over rough ground about *Cobble Brook*, or any danger that it should penetrate into the waste of the *Alloa* coal over which it must pass, or that by any little falling in of that waste, which now and then may happen, the canal may be lost?

N. B. The waste is 20 fathom below the surface, and there are collieries which do not lie deeper, and are wrought under the sea without inconveniency; but as this danger struck the proprietor, it is thought proper to ask the question.

Query 3d. How much per mile ought such a canal at an average to cost?



ANSWER to Lord CATHCART's Queries of the 11th of September, 1767.

To query 1st. THE boats proper in my opinion for a small canal, is not to make them of extraordinary length, but to make them go in pairs; the sternmost boat serving as a rudder to the headmost boat, which not only gives them a very great advantage in turning, but by keeping them short renders them much stiffer, and consequently subject to less wear and tear.

This method is practised in all the rivers and canals communicating with the great levels of the fens of *Lincolnshire*, *Cambridgeshire*, *Norfolk*, &c. where they sometimes go in gangs of four, five, six, sometimes seven, in a string, and where the second boat, steering the first, is followed by all the rest in the same curve; their burthen is from 15 tons to 5.

I cannot, however, recommend so many of them for your purpose, as your voyages will be shorter, the returns quicker, will be managed with fewer men and horses, and in a very narrow canal more easily directed.

The

The dimensions I would recommend for your use are as follows :

		F.	I.	
The head boat	{ Extrean length, - - -	38	0	} Burthen 12 tons.
	{ Extrean breadth, - - -	9	0	
	{ Draught of water loaded, -	2	6	
The stern boat	{ Extrean length, - - -	36	0	} Burthen 10 tons.
	{ Extrean breadth, - - -	9	0	
	{ Draught of water loaded, -	2	4	

These two boats will be drawn with one horse from 2 to $2\frac{1}{2}$ miles per hour, and will be managed by one man on board.

A canal proper for such boats, so as to suffer them to draw freely, should be 12 feet bottom, with 3 feet depth of water ; the width of the water-line will vary according to the batters ; but supposing those at a medium to be 3 to 5, and the surface at a medium 2 feet within foil, the ordinary expence per mile, at 3*d.* per yard, will be 242*l.* and the quantities of ground, including cut and cover per mile, will be about 6 acres *English* measure.

Where great hollows are to be filled, or hills to be cut, the extra expences thereof are to be further allowed, as all the charges of aqueduct and common bridges, tunnels, back-drains, towing-paths, &c. to be added; also allowance made for passing-places, turning-places, &c. which may in a great measure be judged of by my report and estimate already delivered on the subject of the river *Devon*, but cannot be more particular at present, for want of plans, sections, and time.

To query 2*d.* I don't apprehend any extraordinary difficulty with the rough ground about *Cobble Crook*, more than what happens in like cases. As to danger from the falling in of the old wastes of the *Alloo* coal, I don't apprehend they can affect the canal, or the canal affect them, unless there happens a fail immediately under the canal which reaches the surface; in this case, the water of the canal will undoubtedly make its way down into the waste; but if steps are constructed at proper places, as is done in the Duke of BRIDGEWATER's canals, no great quantity can go down, and the breach may be repaired so as to be water-tight as at first; but if wastes of collieries are supported like those which are worked under the sea, and are not used to fall in so far as the surface, I can see no reason for this apprehension.

Aylbhorpe, 8th October, 1767.

J. SMEATON.

P. S. I don't

P. S. I don't know that it is a property of coal-pit water *not to freeze* : it is certain that the water from all mines comes out of the earth at about the forty-eighth degree of FARENHEIT's scale of heat, it must therefore remain unfrozen till by the superior cold of the external air, and surface of the earth, it is reduced to thirty-two degrees of the same scale. If it has any property by which it remains unfrozen, after it's heat is reduced below that degree, it is a peculiarity I am unacquainted with.

MEMORIAL and QUERIES relative to Mr. SMEATON's Report of the Navigation of the *Devon*, of the 14th of September, 1767; from Lord CATHCART, the 14th of March, 1768.

MR. SMEATON, in his report of the *Devon Navigation*, dated September the 14th, 1767, lays down the following proposition.

That the navigation may be carried up from the *Forth* at *Cambus* to old *Sauchie*, by two methods, which he describes and estimates, by making a canal the whole way from *Tillibodie Bridge* to *Sauchie*, or by making a cut from *Tillibodie Bridge* to *Minstrie Lint Mill Dam*, and making use of the bed of the river from thence to old *Sauchie*. Mr. SMEATON estimates the expence of this part of the navigation from the *Forth* to *Sauchie* in the first manner, that is, using the river as little as possible, at 5183*l.* and in the second, that is, using the river as much as possible, at 4793*l.* and though the former, according to his estimate, will cost 390*l.* more than the latter, he prefers and recommends it, for the following reasons, viz. because the distance will be shortened $1\frac{1}{2}$ miles in $6\frac{1}{2}$ miles, and because the works will be in less hazard from floods, and will require less repair.

The following considerations, in favour of the second method, are submitted to Mr. SMEATON, who, when he made his report, was under the disadvantage of being deprived of papers and memorandums relative to the levels, and other circumstances of the *Devon*.

1st. There is already $4\frac{1}{2}$ feet of water in the *Devon*, from the *Lint Mill* as far up as *Coble Brook Ford*, so that the work at A, in Mr. SMEATON's Plan, estimated at

975*l.* being in water 9 feet deep, cannot be necessary, the price of it ought to be added to the balance in favour of the second method, and will raise it from 390*l.* to 1465*l.* which is an object.

2dly. From *Coble Crook* to *Hennie's Burn*, a convenient place for boats to lie in, a little below *Sauchie* new engine, there is a rise of no more than 3 feet 2 inches; at *Coble Crook* there is a foundation of rock, with rocky and steep banks on each side, and a very good quarry close to it, so that there seems no reason to believe a dam of 3 feet 2 inches high, and a lock of that rise, can possibly cost a sum, upon any principle of Mr. SMEATON's other calculations equal, or near equal to 975*l.* but it may be proper to leave that article as it stands, because if the people of *Alloa* are cut off from *Alloa*, by the ford being destroyed by the dam, there will be a necessity to build a bridge over the *Devon*, probably at *Sauchie*, as there is a good foundation and a quarry at hand, which will cost 200*l.* if so, the expence of the second method will remain 3818*l.*

3dly. If the first method is used, the expenditure of water from the *Tillicoultry Dam*, which supplies *Sauchie* engine, will be increased by the consumption of the *Sauchie* and *Collyland* coals, which in the second method would embark in the river above the *Coble Crook Dam*, and would waste none of the water belonging to the *Tillicoultry Dam*; and it must be remembered that the *Sauchie* engine can on no account give up any water which it has or may have occasion for, and has at present a right to.

4thly. The greatest difficulty attending works now to be carried on in *Scotland*, will be the want of labourers. The execution of the second method will not require above one-sixth part of the labourers the first would require, because the digging is as $\frac{1}{2}$ to 3, and the lockage as $3\frac{1}{2}$ to 20.

5thly. As the *Lint Mill* and *Tillibodie Mill Dams* have been proof against the greatest floods, it may be presumed that the *Coble Crook* work, which is better placed, and will be better, will be equally safe, and will be a security to the works below.

Query 1st. Upon the whole of these considerations, does Mr. SMEATON admit the deduction of his work at A, and its expence 975*l.* Does he recommend the canal from *Sauchie* to *Tillibodie Bridge*, or the river from *Sauchie* to the *Lint Mill*; and if the latter, would he place the lock at *Coble Crook*, or at any situation above it, in which case the *Coble Crook Ford* must be deepened?

Proposition

Proposition 2d. Mr. SMEATON proposes to carry up the navigation from *Sauchie* to *Tillicoultry Burn Foot* by canal, to raise the river by a dam to supply that canal, to cross the river and lock up into a cut on the north side and on the level of *Tillicoultry Dam*, to repass the river above *Tillicoultry Dam*, and lock up into a cut on the level of the tail-race of the *Rack Mill*, and in that cut to proceed to *Mellock*, and for these operations he makes the following charge :

	£.	s.	d.
From <i>Sauchie</i> new engine to <i>Tillicoultry Burn Foot</i> , - - - - -	1304	11	0
From thence, through the river, to the next cut, - - - - -	703	7	0
Cut into <i>Tillicoultry Dam</i> , - - - - -	729	19	0
Cut from thence to <i>Mellock Foot</i> , - - - - -	1044	3	0
Towing Path, at 15 <i>l.</i> per mile, for 2 $\frac{1}{2}$ miles, - - - - -	37	10	0
	<hr/>		
	£. 3819	10	0

It is submitted to Mr. SMEATON, whether the following method would not be preferable, for the following reasons, viz. To enlarge the *Sauchie* aqueduct to the size of a canal from the *New Engine* across the road leading to *Tillicoultry Bridge*, to carry it either on the same level as far as *Mellock*, being 2 miles and a half, and there raise it by a lock to a level of the tail-race of the *Back Mill*, and continue it from thence the space of 1 mile further to the tail-race of the said mill, or by placing the lock nearer *Tillicoultry Bridge*, and raising the level of the canal earlier, as may be thought most convenient ;

1st. Because this work will be entirely out of the reach of the highest floods, and the works at *Tillicoultry Burn Foot*, the most precarious and expensive, in point of repairs, in the whole navigation, will be saved, and the price of it being 703*l.* will probably more than answer the extra expence of carrying a canal along the south bank of the river, betwixt *Tillicoultry Bridge* and *Tillicoultry Dam*, where the ground is more narrow and difficult, as well as the additional length of canal beyond Mr. SMEATON's calculation, amounting to 6 furlongs, which, it is apprehended, will require less expence in digging and in land than the shorter place, which is proposed to run through ground much more valuable, and to be cut much deeper within foil, especially betwixt *Sauchie* and *Tillicoultry Burn*.

2d. Because by keeping the canal 20 feet above the level of the river at *Hennies Burn*, it may be, with the same expence, communicated by locks at that point, as if the lockage had been dispersed along the whole course of it ; and if either money or

hands should fall short, the execution of these 20 feet of lockage might be postponed, and an immediate communication opened, for the time being, betwixt boats coming up the *Devon*, as far as *Sauchie* from the *Forth*, and boats coming down from the *Rack Mill* to *Sauchie*, till the junction is completed by locks.

3d. Because, by carrying up the navigation 1 mile beyond *Mellock*, no additional lockage will be incurred, as the lock necessary is marked in Mr. SMEATON's plan, and the expence included in his estimate; so that the additional expence will be no more than the digging, land-bridges, and towing-path of 1 mile, amounting, according to Mr. SMEATON's estimate, to 769*l.* and the benefit of water carriage will be communicated to *Dollar* and the country above it, as there is now a bridge at the *Rack Mill*, and to the *Blairngon Colliery*, to which a road for the carriage of coal may easily be made; and it is supposed that the produce of that colliery, whether carried to the sea or to the north country, would go down the *Devon*, which would both increase it's produce and raise it's tolls.

Query 2d. Is Mr. SMEATON of opinion, that the navigation ought to be carried up to *Mellock* in the manner above described, keeping the south side of the water the whole way, and that the expence will not exceed the above estimate of 3819*l.* 10*s.*? That it ought also to be carried up to the *Rack Mill*? and that the additional expence will not exceed 769*l.*—in all 4588*l.* 10*s.*? To which supposing 3818*l.* to be added, for the space betwixt *Cambus* and the *Sauchie*, the two sums will make 8406*l.* 10*s.* and with 843*l.* 10*s.* for extraordinaries, the whole expence of the navigation from *Cambus* to the *Rack Mill*, for boats drawing 3 feet water, will amount to 9250*l.* according to the principles of Mr. SMEATON's estimate.

Query 3d. As the boats described by Mr. SMEATON, drawing 3 feet water, are only fit to go down the *Forth*, as far as *Carron*, with which the *Devon*, as both their produce in coal cannot have much intercourse, it is desirable that a foot of additional depth should be given to the works below *Sauchie*, in order that they may be passable for boats drawing 4 feet water, 13½ feet wide, 42 feet long, and carrying 25 tons; such boats being constructed in the *Clyde*, for the navigation of the highland seas, and therefore supposed fit to go to *Leith*, and in summer to the north country: Query, What additional expence would this alteration cost? It is supposed, that if a foot were to be added to the *Linn Mill* and *Tillibodie Mill Dams*, the river would still be within foil, and would require no banking, and, if so, that a foot more water would be

be thrown into the two cuts without any farther expence for extra digging, and that in the river there is a sufficient depth.

Query 4th. What would be the expence per mile of deepening the canal 1 foot between *Saucie* and the *Rack Mill*?

Query 5th. The ground being favourable for cutting a canal, on a dead level, from the *Lint Dam* to *Stirling Bridge*, where it might be communicated, by a lock or locks of 1.1 feet fall, with the *Forth*, it would be proper to include this circumstance in the act of Parliament, because not only all the coals for the north country sale would be conveyed by it to *Stirling Bridge*, but also the *Upper Forth* boats coming to the *Devon* for coals would lock up at *Stirling Bridge*, rather than *Cambus*, as they would save near 12 miles each trip; the expenditure of water would be diminished rather than increased, because the lockage is not computed at more than one lock-full per day. The coals for the north country and for *Stirling* would waste no water, which they must do were they to go down the *Devon* and up the *Forth*, and the boats coming and going from and to *Craigforth* would waste the same water, whether they entered the canal at *Stirling Bridge* or the *Devon* at *Cambus*. Mr. SMEATON estimates 2 miles of canal between *Mensrie Bridge* and *Alloa*, at 2400*l.* and the lockage from the level of the former into the *Forth* of the latter, at 1100*l.*—in all, 3500*l.* Query, The height being the same, and the distance one third greater, is not 4700*l.* an adequate price for the branch from the *Lint Mill Dam* to *Stirling Bridge*, being 3 miles in length, and for the lockage into the *Forth*? viz. together with the former sum of 9250*l.* would make in all 13950*l.* for the navigation of the *Devon*, and for the branch to *Stirling*.

PERTH BRIDGE.

MEMORIAL for Mr. SMEATON.

August, 1763.

THE Justices of Peace for the county of *Perth*, at their quarter sessions in May last, having entered into several resolutions to promote a scheme for building a bridge across *Tay*, at or near *Perth*, did, among others, appoint a committee of their number to meet with and consult Mr. SMEATON on this subject.

These gentlemen now take this opportunity of applying to Mr. SMEATON, that he will visit and inspect the river at and near the town of *Perth*, and report to them the proper place for erecting such a bridge, paying alwise a particular attention to the safety of the town of *Perth* and the adjacent grounds, as well as the bridge.

He will be pleased, at the same time, to consider how far a stable bridge, of any other materials than stone, can be constructed, so as to answer all the requisite purposes of carriages, &c. and be made more properly adapted to the situation and rapidity of the river and safety of the town.

As Mr. SMEATON will satisfy himself as to the measures of the breadth of the river at the different places, it is only necessary to observe, that the land-floods often swell the river, with great rapidity, 14 feet higher than the water is in summer, and that the stream-tides flow to the height of 8 feet, or thereby, opposite to the *North Key*, where the former bridge was built, and that the bed of the river is generally hard gravel.

If Mr. SMEATON should approve of the scheme, and determine on the situation, it will be proper that, with conveniency, he make a plan of such bridge as he shall judge most eligible; for which plan, and his trouble in visiting the river, the committee will properly gratify him.

The REPORT of JOHN SMEATON, Engineer, concerning the practicability of building a bridge over the river *Tay*, at *Perth*, in answer to a memorial thereupon addressed to his consideration by the committee of Justices, bearing date August, 1763.

HAVING, pursuant to my instructions contained in the said memorial, examined the soundings of the river *Tay*, at and near the town of *Perth*, in the month of August last, as well as other circumstances relative thereto, I am of opinion as follows :

1st. That from the rapidity of the river, and the quantity of ice, said to come down the same in winter, that though a bridge may be built of timber sufficient to answer the purpose for a number of years, yet, to give the same the necessary degree of stability, will, in it's first erection, be near as expensive as if built with stone, and, from the perishableness of the materials, be subject, in the course of a few years, to great and expensive repairs ; and withal considering that this is a part of the country where good workable and durable stone is cheap, and good oak timber dear, I can by no means recommend a bridge of any other materials than of stone.

2d. I am of opinion, that it is practicable to build a durable and useful stone bridge at or near the town of *Perth*, and without any danger or hazard to the town likely to arise therefrom, provided it be constructed with a sufficiency of water-way.

3d. I am of opinion that two of the most proper places for the situation of a stone bridge is either in a right line with the *Town Street*, nearly where the old * bridge was erected, or a little above the town, from the *Tenter* in the *North Inch* to the opposite shore in *James Bissett's* garden.

4th. Of these two places, I prefer the latter, on account of less difficulty and less expence ; for though the river is wider at the latter situation than at the former ; yet, as the depth is considerably less, the expence and hazard of making coffer-dams for laying the foundation of the piers, will be very considerably greater opposite the town than at the *North Inch* ; and the expence of making dams and clearing the foundation will

* Built by *John Mylne*, and swept away (in 1621) by a mighty inundation.

be further enhanced by the remainder of the old piers, all or most of whose foundations probably remain in the river.

5th. In consequence of this preference, I have made a design for a stone bridge to be erected from the tenter at the *North Inch* to the opposite shore, which accompanies this report, and have also annexed an estimate of the expence; the width of the river here I make to be about 653 feet.

6th. It is to be remarked, that it appeared to me, from sounding, that the bed of the river was every where a firm gravel, sufficient to support the weight of such a bridge as I have proposed; but from information I learnt, that, in digging near the river, there is every where a stratum of sandy clay, laying about 4 feet under the bed of the river, and about 4 feet thick: now, as some excavation in the bed of the river will be necessary, this will reduce the upper crust of gravel so thin, that the stratum of sandy clay, being of a yielding nature, the bridge cannot with safety be trusted upon it without piling, nor even with piling so securely; nor can it be done at so small an expence as by carrying the foundation down to the surface of the under-bed of gravel, which is said to reach to an unknown depth. For these reasons, I have supposed the foundation of the bridge to be laid 8 feet under the bottom of the deepest part of the river, where the bridge is proposed to be fixed, and have estimated the expence accordingly; but if it should turn out, on boring or digging, that the upper stratum of gravel is considerably *thicker* than here supposed, or that no such stratum of sandy clay subsists at this place, then a considerable expence will be saved, the foundation being here supposed to be laid 10 feet under the surface of the river at low water in dry seasons. On this account, I would advise the foundations to be tried before any thing definitive be determined.

7th. It is to be further remarked, that the prices in the following estimate are such as are usual for such kind of work in this part of the kingdom, and such as I apprehend it may be done for at *Pertb*; but, for further satisfaction, if the committee please to order my estimate to be drawn out, with the quantities there inserted, without the prices, they will have an opportunity of having the sentiments of the workmen of the country thereupon, by causing them to fill up the same; only regarding the coffer-dams, as the method therein proposed cannot be explained without models, nor indeed successfully practised but by a person experienced therein; their sense thereupon will be best had, by stating the internal circumference of the dams, and that they are, at a medium, to pen out 6 feet water: the committee will thereby come at the cost thereof in such method as the workmen themselves would propose; but, as the method is put in daily practice

practice here, the committee may depend on it's being practicable, and at the prices stated, unless there is a material difference in the value of timber and labour here and at *Perth*.

ESTIMATE for erecting a Stone Bridge over the river *Tay*, at *Perth*, from the *Tender* at the *North Inch* to the opposite shore; to have 7 principal arches, extending 605 feet 9 inches, and in the whole length 893 feet; to be 22 feet in the clear, within the parapets, and to have a walking path on the south side of 4 feet wide.

By JOHN SMEATON.

COFFER DAMS.

THERE being, according to my information, a stratum of hard gravel at the depth of 8 feet below the bed of the river, I propose to found the piers immediately thereupon, without piles or grating; and in order to come at this foundation, as the river will not in it's low state be above 2 feet deep of water, and does not rise at ordinary spring tides more than 8 feet above this mark, and at neap tides little worth regarding, I reckon that a dam, capable of holding out the water 4 feet above it's low state, will enable the workmen to work nine or ten days successively between each spring tide; and I apprehend a dam of this height will not only be constructed at a much less expence, but be less subject to hazard, than if raised so as to pen out the spring tides; this dam to have a sluice upon it, to let the water in and out, as occasion shall require; and, for the more safe and ready excavation of the matter, I propose the dam to be placed at a medium 16 feet distant from the base of the pier, and to be of an elliptical figure, the better to resist the tides and floods.

	£.	s.	d.
To 26 gage piles, of 10 feet long, at 10 s. each,	13	0	0
To 2328 feet superficial of plank piling, 9 $\frac{1}{2}$ feet long, at 1 s. 2 d.	135	16	0
To 122 cube feet of timber, in string pieces, for supporting the pile heads, at 3 s.	18	6	0
To extra work, in making a sluice for letting the water in and out,	2	10	0
	<hr/>		
To timber work in one coffer dam,			£. 169 12 0

* In the estimate delivered in, this number was by mistake called 2 instead of 12 s. and the dependent sums being less accordingly, made the articles of the coffer dams be 724 l. 2 s. instead of 726 l. 2 s.

				£.	s.	d.	
			Brought forwards,	169	12	0	
To pile shoes, for 26 gage piles, at 1s. each,	-	-	-	1	6	0	
To plank pile shoeing, 245 running, at 6d.	-	-	-	6	2	6	
To 25 bolts for the string pieces, at 2s. each,	-	-	-	2	10	0	
To extra iron-work about the shuttle, and contingencies,	-	-	-	2	0	0	
To iron-work about one coffer dam,	-	-	-		11	18	6
A coffer dam complete,	-	-	-		181	10	6
The materials for the first pier is supposed to be of half value toward each succeeding pier, which will therefore be No. 6. at 90l. 15s. 3d. each,	-	-	-		544	11	6
Coffer dams for the whole	-	-	-		726	2	0

Excavation and drainage.

To excavation of the matter 722 yards, at 6d. comes to, each pier,	-	18	1	0
To drainage of the water, supposed equal to 50 days, at 20s. per day,				
per pier,	-	50	0	0
To excavation and drainage of 6 piers, the 2 abutment piers, and foundation for the wing walls, being supposed equivalent to 2 piers, the whole will be equivalent to 8 piers, at 68l. 1s. each,	-	68	1	0
			544	8 0

Masonry in the piers and abutments below the springing of the arches.

To 1080 feet superficial of ashler in each pier below water, at 7 d.	-	31	10	0
To 1176 ditto above water, at 8 d.	-	39	4	0
The whole pier, in solid, contains 467 cube yards, including labour, carriage, tarras mortar 6 inches in the outside joints, and all materials, at 5 s. per yard,	-	116	15	0
N. B. The ashler being at least 20 inches bed, and cubed into the solid, at 5 s. per yard, is supposed to pay for the tarras mortar and extra labour in setting thereof.	-			
To capping the pier with solid blocks jointed between the springer stones, 600 cube feet, at 6 d.	-	15	0	0
To capping the ends of the piers 148 feet superficial, at 8 d.	-	4	18	8
To 6 piers, and 2 abutment piers, each reckoned as a pier, that is No. 8, at 207 l. 7 s. 8 d.	-	1659	1	4
To walling-in the west land stool to bring it up to the springers, to be at a medium 5 feet thick, containing 490 cube yards, at 5 s.	-	122	10	0
To hammer-dressing that part of the wall that comes in view below the plinth, containing 666 feet superficial, at 1½,	-	4	3	3
To working the plinth, being before reckoned as solid, containing 990 feet superficial, at 3 d.	-	12	7	6
To 78 cube yards of masonry in the east land stool, to bring it up to the height of the springers, at 5 s.	-	19	10	0
To setting under the west abutment arch to prevent the water from affecting the foundations, 1393 feet, at 4 d.	-	22	11	0
Masonry in the piers and abutments below the springing of the arches,	-			
			1840	3 1

Centering for the arches.

To timber in one rib, 416 cube feet, and for 6 ribs	-	2496	cube feet.						
To timber in 30 bearing piles, and 5 cap-trees for supporting the ribs,	-	750							
To stays and bracings between the ribs to keep them upright		75							
To covering for the centers in square scantlings	-	525							
To additional work to make the centers fit the larger arches,		188		£.	s.	d.	£.	s.	d.
To timber in a center compleat, at 3 s. per foot,	-	4034		605	2	0			
To ironwork in the six ribs, 1852 lb. at 5 d.	-	£. 38	11	8					
To ditto in pile-shoes and hoops, 662 lb. at 5 d.		13	15	10					
To spikes, nails, and other contingent articles,	-	5	0	0					
To ironwork for one center,	-				57	7	6		
To one center compleat,	-						662	9	6
To a set of piles and cap-pieces ready prepared for driving in the second arch before the first center is struck, containing 750 feet, at 2 s.	-						75	0	0
To 5 booms, containing 375 feet of timber, at 2 s. to be fixed as struts between the piers of the second arch, while the center is taking down from the first, and putting up in the second,							37	10	0
To taking down the center, drawing the piles, driving ditto, and setting up the center six times, repairing and making good what is wanting, at 9 d. per foot solid upon the timber, which being 4034 feet, comes to 151 l. 5 s. 6 d. each time, and for six times,	-						907	13	0
To taking down and putting up the booms five times, at 6 d. per foot,	-						46	17	6
To centering for one of the small arches, at 1 l. per square,	-						20	0	0
To taking down, removing, and setting-up ditto in the other arch,	-						5	0	0
Centering for the bridge, compleat,	-						1754	10	0

Masonry in the superstructure.

To 15850 feet superficial in the soffite of the main arches, being three feet thick, set in place, and mortar included, at 20 d.	-						1320	16	8
To 2000 feet superficial in the soffite of the abutment arches, at 12 d.	-						800	0	0
To blocking up the spandrels of the arches solid, 6 feet high, containing 473 cube yards, at 5 s.	-						118	5	0
To cube masonry in the spandril walls, abutments, and wing walls, from the top of the piers to the top of the cordon, containing 3776 yards, at 5 s.	-						944	0	0
To hammer-dressing the plain superficies thereof, containing 33984 feet, at 1½	-						232	8	0
In the parapet 11856 feet superficial on both sides, being 15 inches thick, stone, workmanship, mortar, and setting ditto, at 6 d.	-						269	8	0
To 18382 feet superficial in the faces of the arches, bands, and keys, the cordon, mutules, capping, and pedestals, which being before reckoned in solid, except their projecting parts and all square work, I put at 4 d. per foot,	-						306	7	4
							3271	5	0

Carried forwards

	£.	s.	d.
Brought forwards	3271	5	0
To 2160 feet superficial in the 12 eyes, and 640 feet in the terminating pillars, in the whole			
2800 feet superficial of circular work, (being before included in the solid) at 6d.	70	0	0
The walking-path, being 4 feet wide, contains 3641 feet superficial, stone, working, and laying, at 7d.	106	12	0
Masonry in the superstructure,	347	17	0

GRAVEL.

To 10948 cube yards of gravel to fit up the spandrels and wing walls, and form the road, at 9d. per yard,	410	11	0
N. B. No part of the road is considered except what falls within the walls of the bridge.			

CONTINGENCIES.

To piling engines, pumps, and other utensils, supervival, unforeseen accidents, and expences,	1000	0	0
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ABSTRACT.

To coffer dams,	726	2	0
Excavation and drainage,	544	8	0
Masonry in the piers and abutments below the springing of the arches,	1840	3	1
Centering for the arches,	1754	10	0
Masonry in the superstructure,	3447	17	0
Gravelling the bridge,	410	11	0
Contingencies,	1000	0	0
Total	9723	11	1

N. B. In the batterdeaus and centers there will remain at least 5763 cube feet of timber, which, if sold for 9d. a foot cubic, will amount to 214l. 2s. 3d. besides ironwork, engines, and utensils, which, it is presumed, will be sufficient to make the road to and from the bridge.

The prices in the preceding estimate includes all labour, carriage, mortar, and setting-up in place, unless otherwise particularly expressed.

EXTRACT Minutes of the Trustees for building a Bridge over the *Tay*,
at *Perth*.

AT *Perth*, the 26th day of September, 1765 years, at a meeting of the trustees for building a bridge over *Tay*, at *Perth*, four letters from Mr. SMEATON to the Earl of KINNOUL, dated 12th of July and 1st of August, 1764, and 9th of April and 3d of May, 1765, being read, upon consideration thereof, and of the sums subscribed in free gift towards building the bridge, it is the opinion of this meeting :

1st. That the work shall be begun next year, by raising an experimental pier, under the direction of Mr. SMEATON, as proposed by him, and that the materials necessary for raising such a pier be prepared in due time.

2d. That Mr. JOHN ADAM, architect, is a proper person to be employed in preparing such materials.

3d. That Mr. ADAM be desired and authorised to open, and try, proper and convenient quarries for that purpose.

4th. That a committee be appointed to confer and treat with Mr. ADAM, and to receive proposals from him concerning such materials, which proposals he is desired to lay before the Committee.

5th. That the said Committee shall, from time to time, as they shall think proper, report their proceedings to a meeting of the trustees, and that the clerk shall call a meeting for that purpose, whenever the said committee, or any two of them, shall desire it.

6th. That the Earl of KINNOUL ; Lord GRAY ; Mr. CRAWFORD, of *Errol* ; Mr. GREENE, of *Balgovan* ; Sheriff SWINTON ; Mr. BELCHES ; Provost SIMPSON ; Mr. OLIPHANT, of *Rossie* ; Mr. CRAIGE, of *Dumbarney* ; Messrs. ROBERTSON, elder and younger, of *Tullibeltan* ; Mr. RICHARDSON ; Mr. MERCER ; Mr. WOOD, Dean of *Guild SANDEMAN* ; Baillie FYFE ; Mr. WILLIAM SANDEMAN ; Baillie RAMSAY ; Baillie MARSHALL ; Baillie FAICKNEY ; Mr. THOMAS ANDERSON, and other Trustees that shall please to attend, shall be of the said Committee ; and that five shall be a quorum ; and that Mr. MERCER shall be convener.

7th. That

7th. That the clerk shall transmit extracts of the foregoing resolutions to Mr. SMEATON and Mr. ADAM. Extracted from off the record of the minutes of the said Trustees, by

PAT. MILLER, Clerk.

EXTRACT Minutes of the Commissioners for the Bridge over the *Tay*, at *Perth*, in relation to Mr. JOHN GWINN trying the foundation, &c. and his report, 1766.

AT *Perth*, the 27th day of February, one thousand seven hundred and sixty-six years, sederunt, the Earl of KINNOUL, Provost SIMPSON, Mr. MERCER, Mr. WOOD, Baillie MARSHALL, Mr. WILLIAM SANDEMAN, Mr. DUNCAN, Mr. ALEXANDER FAICKNEY, Mr. THOMAS ANDERSON, and Mr. SAMUEL SAMPSON, commissioners appointed by Act of Parliament for building a bridge over the river *Tay*, at *Perth*.

The Earl of KINNOUL chosen Præses.

The committee appointed by the commissioners the 26th day of September last, gave in the following report of their proceedings, to wit,

At *Perth*, the 20th day of February, faierly ditto, and sixty years, at a meeting of the committee of the commissioners for the bridge over the *Tay*, at *Perth*, sederunt, the Earl of KINNOUL, Provost SIMPSON, Mr. MERCER, Mr. WOOD, Mr. JAMES DUNCAN, Mr. THOMAS MARSHALL, Mr. ALEXANDER FAICKNEY, Mr. THOMAS ANDERSON, the Earl of KINNOUL Præses.

The committee having communed with Mr. GWIN, the person recommended and sent by Mr. SMEATON, direct him to continue boring at that place, which Mr. SMEATON pointed out to be the properest place for the bridge, according to the opinion he had formed when he surveyed the river, until he has discovered, as well as he is able, the metals that are to be found in the bed of the river, the whole way across the same, and that he would likewise bore across the river opposite the town-house, and in any other part he shall think proper to try; and that he will report to the commissioners, at their meeting the 27th instant, what place he in his judgment, upon full consideration of all circumstances, and upon the best information he can get of the
state

state of the river at the different parts in the time of spate, thinks the most eligible for erecting the bridge, with his reasons for such opinion ; and that he will also report the particular state of the metals as he shall find them at the different places by his boring, and that he shall likewise include in the said report a particular of the materials he shall think necessary in his branch of business for erecting the experimental pier this summer, always understanding that Mr. SMEATON is willing that such pier be erected in the most difficult part of the river, and also what number of hands it will be necessary for him to employ in his branch, in order to prepare every thing for erecting such pier as early this spring as the state of the river will admit ; and Mr. SMEATON's other engagements will allow him to come here for that purpose, distinguishing what men he thinks it absolutely necessary to bring with him, and the terms upon which such men may be engaged, and what number of hands he would have engaged here ; and lastly, that Mr. GWIN will acquaint the commissioners at what time he proposes to return, to begin these preparations.

The committee order the clerk to communicate to Mr. GWIN Mr. SMEATON's plan, estimate, and report anent the bridge, with his letters to the Earl of KINNOUL, and also to the clerk there anent.

The committee empower Mr. MILLER, their treasurer, to defray the expence of quarrying the stones, and to pay Mr. GWIN such sums as shall be necessary for preparing the works which he is engaged in, and for providing materials.

The committee direct the treasurer to draw upon Mr. ANDREW DRUMMOND for such sums as he shall inform him, from time to time, are in his hands, and to remit the same to the bank at Edinburgh, with the profits of the exchange.

The committee direct the treasurer to remit to the bank such sums as shall come into his hands, in the most proper manner.

The committee appoint that these their proceedings to be reported to the next meeting of the commissioners.

(Signed)

KINNOUL, P.

The clerk produced a copy of a letter from Mr. SMEATON to the Earl of KINNOUL, dated the 8th instant, and also two letters from Mr. SMEATON addressed to the clerk, dated the 6th and 10th instant, all of which were read.

Mr.

Mr. GWIN gave in to the meeting his report, of which the tenor follows :

The REPORT of JOHN GWIN, in answer to orders by him received, and appointed to his inspection and consideration at a meeting of the commissioners for building a bridge over the river *Tay*. February 27, 1766.

1st. UPON sounding with what instruments was practicable to get down to prove the stratum of matter in sundry places across the river *Tay*, from *North Inch* to the opposite shore in JAMES BISSET's garden, as well as the state of the river and metals would permit, find the stratum of matter in the different soundings are as follow: that on sounding and boring in sundry places both above and below JAMES BISSET's garden, to the extent of about 150 feet in length up and down stream, found a rock close in shore upon an average lying upon 2 feet 9 inches below the top surface of the gravel, and extending itself from the shore, towards *North Inch*, as near as I could judge, about 300 feet, before I could exactly say I thought it left, and continued to be very level, not varying one foot in depth in the above length. This top crust, or supposed stratum of rock or hard cemented gravel, consists equally alike in all different places of trial by boring, and appears to be a shaly hard consistence for about 8 inches thick; but upon further speculation, to prove its consistency of metal, found that we could force a sharp-pointed iron bar down 6 feet deep (in some parts 8 feet deep) into the said stratum of shaly matter, always observing the bar went moderately easy after it got through the upper crust beforementioned, and did not begin to fasten till at about 8 feet or 9 feet in general, and then it came to a matter much more firm and solid. From this place, which is not quite the half over to the *North Inch*, the stratum grows somewhat softer after we got down 7 feet from the top surface, which seems to run, on a medium, nearly on a level, it being a stratum of sound firm gravel, and then, for about 2 feet 9 inches, it appears to be a sandy gravel, (by what our rods brought up) and under that, at about 10½ feet from the top surface, on an average, we come to a firm sound gravel, as before.

Upon boring on the shore in JAMES BISSET's garden, in two places, at the distance of 30 feet from the water's side, find the stratum of matter to be from the top surface to 6 feet deep a blue corn mold earth, and from that down 5½ feet a quite shear sand intermixed with a little gravel, which both together makes 11 feet 6 inches, at which depth we came at the rock, which lies nearly level, and rising in its bed but very little up the hill. On the *North Inch* side on land we bored, we find corn mold earth to the depth of 5 feet from the surface, and from that to the depth of 3 feet a sharp shear sand, then came to a loose gravel for about 2 feet, after which it continues looseish to about the depth of 8 feet, at which depth it appears to be a quite solid gravel, and is all the particular

particular situations of the stratum of matter consisting in the bed of the river, across from shore to shore, at the abovementioned place, to the best of my opinion.

2d. Upon sounding the aforesaid river from the town-house to the opposite shore called bridge end, find the metals in the bed of the river as follows. Having drove a sharp pointed iron bar in sundry places up and down stream for near 120 feet in length, but could find no place to get the bar down from the upper surface about 4 feet before it met with some of the ruins of the old bridge, which lay spread up and down in that channel for about 60 yards facing the high street, and extending about 80 or 100 feet breadthways across the river; after which, on sounding from thence to about 80 feet of the opposite shore in sundry different places, found the stratum of matter so soft, as to admit a bar being forced easily down into it 12, 14, and 16 feet, and even at that depth no solid matter appeared. The soil, from what I can judge, is a sandy clay, at about 6 or 7 feet from the top surface, which is all the particular description of the strata of matter in the above situation, to the best of my opinion.

3d. Regarding which of the two before-mentioned places is properest to erect the bridge, my opinion is, that the suitablest place for the bridge to be built near the town of *Perth*, is from the *North Inch* to the opposite shore, in JAMES BISSET's garden, (for reason 1st.) The river is more extensive in breadth than in any other place adjacent to the town. (2dly.) In extreme floods the water having liberty to extend itself to a great surface, and by the intended situation of the bridge being at a proper distance from the mill lead, consequently will give room and scope for a great quantity of water to issue in there on the down-stream side of the bridge, which will cause a lethe of water to constantly be recoiling back to the bridge, and meet the currency, and thereby ease in a great measure the pressure and weight on the bridge. (3dly.) Its situation in this place is much more desirable, as it is across a ford, which by the best accounts I can learn has not been known to shift these many years. (And lastly.) It has been remarked, that during the late storms, wherein the *Tay* has discharged great quantities of ice, which has floated up and down with the tide, it was not known that scarcely any ice went up above the said ford, but has been known to gorge up the river in different places to an almost incredible height below the said ford, particularly at or nearly opposite the town-house, which would be a very great obstruction to the water-way in a flood time, provided the bridge was pitched upon to be built across this part of the river; besides, another reason in my opinion against this situation not being suitable is, that the river is more contracted from shore to shore, it being but 567 feet across from the town-house wharf to THOMAS TYFF's house, besides its bounds are shorter than that, as much as it is across from the wharf side to his house, which is 34 feet, which reduces the water-way

way so much less; and (3dly,) on continuing the proper length of the bridge, find that according to plan the bridge foot will terminate above 50 feet above *Waller Gate Street*, which will render the low rooms of the dwellings contiguous thereto invalid, by the bridge being so high above them on both sides, supposing all other circumstances agreed with its situation.

4th. Regarding the part of the river in which the first pier should be fixed, am of opinion, that one of the center arch piers will be as difficult as any, for reason, if we are to go down to that lower bed or stratum of hard gravel, it will be a difficult matter to drain it, for the getting out the excavation and foundation laying, or the third pier nearest the bridge end shore, it being the deepest water there.

5th. Regarding the quantity and quality of sundry materials in timber necessary for the erection of one pier, in making a coffer-dam and pumps and engines, and all other materials, &c. such as tackles and shear-poles for the masonry, and hand and wheel barrows for the excavation, and likewise, in case the pier should be ordered by Mr. SMEATON to be piled in the foundation, the stuff wanted will be as followeth: for the coffer-dam and other uses 2274 cube feet of oak and elm, and 150 cube feet of *Riga* timber, about 200 superficial feet of ash plank for barrows, about 15 *Affar* baulks, 20 feet long, for stages, and tackle poles, &c. about 30 *Dantzick* 3 and 4 inch planks, 20 feet long, for stages and runs for the barrows in the excavation, likewise about 30 inch and half *Dantzick* planks for engines, and pumps, &c. about 14 or 16 feet long; and lastly, if it comes to be a timber foundation, (not that I pretend to know in what manner Mr. SMEATON will pitch on it to be done,) but only in case it should so happen that he thinks it necessary; in such a case, I have made a rough calculation what stuff we should have in readiness against such thought as may to him seem best, which appears it cannot be less than 1000 cube feet of oak and elm, though I think it would be full enough, only it would be proper to have some to turn our hands on.

Regarding what number of my workmen I think necessary to bring with me from *England*, I intend to bring two men and my apprentice. As to terms, Gentlemen, as they will be employed in your service about five months, or nearly so, and then have to go home back again, I think I cannot engage them otherwise than at 14s. per week each man, and the apprentice to be 7s. with their time and moderate expences on the road going and coming paid them.

7th. Regarding the quantity of other workmen necessary in my branch for carrying on the pier, to be assisting with my men, I think four carpenters and ten labourers will be

be sufficient for the expediting the work ; but the latter will not be wanted till we begin to take off the water.

With the blessing of God, if I continue in good health, I propose to be at *Perth* in six weeks time, from the setting off on my journey to my coming again, provided all materials, or part to begin, be got to a proper place to work, upon notice, which I presume will be sent ; and I think, if agreeable to you, Gentlemen, that Mr. SANDEMAN's saw-mill will be the properest place to work up the materials, as the stuff may be sawed by the mill and worked up there, and then sent down to the work by water as wanted, and not be liable to be any of it lost by floods.

Signed, JOHN GWIN.

Which report being read, the Commissioners direct Mr. GWIN that he will immediately, upon his return to *England*, communicate the said report to Mr. SMEATON, and desire Mr. SMEATON to ascertain the materials which he shall think most proper and necessary for the timber work that is to be prepared for erecting the experimental pier ; and that he would, as soon as possible, transmit to Mr. PATRICK MILLER an account of the materials so ascertained by him.

The Commissioners approve of Mr. GWIN's terms upon which he proposes to bring down from *England* the two workmen and his apprentice.

The Commissioners recommend it to Mr. GWIN to regulate his return so that the necessary preparations may be ready at the time it will suit Mr. SMEATON's convenience to be here ; and they direct their clerk to deliver to Mr. GWIN a copy of their minutes in so far as relates to his report.

Extracted from the records of the said Commissioners by me

PAT. MILLER, Clerk.

DESCRIPTION and METHOD of fixing the foundation of the second pier of *Perth Bridge*, according to the plan.

Method of fixing the coffer-dam.

THE gravel turning out harder than was expected in the last pier, and it taking up much time in driving the piles of the coffer-dam down to their proper depth, and also finding them very difficult to draw, and much shattered when drawn, I propose for this pier that as many additional piles be procured as will set the whole at the distance of 9 feet from sheeting of the base of the pier, and to drive them no farther than to fix them firm in the ground, which if that happens at 2 feet will be sufficient. The dam being then completed to its proper height, in order to guard against filtration of the water under the bottom of the piles, I propose to throw in all round on the outside a quantity of gravel and corn mold earth mixed together, so as to lay rather sloping against the piles, and extending about 6 feet all round: the gravel being mixed with the earth, will not only augment its quantity, but prevent its being carried away by the stream, the use of the earth being to choak up the chinks and pores of the gravel upon the bed of the river. I apprehend about a cube yard of compound matter, to a yard running, thrown in, will be sufficient, observing to begin the work at the salient angle up stream, and proceeding gradually downwards on both sides, closing at the salient angle down stream.

Method of making the excavation.

The pumps being fixed, and the water pumped out, begin the excavation no larger than the base of the pier, and having got down a space in the middle to its proper depth, increase it in width and length till the area is clear for driving the piles upon which the foundation frame is intended to rest, and no more, leaving the matter on the outside of that area to form its own slope toward the coffer-dam, so that the rest of the area will be left solid, to support the sheeting of the dam; and if any part seems feeble, or likely to give way, let it be strengthened by driving piles for supporting slate on edge, as the nature of the ground and circumstances shall shew to be necessary, observing, in beginning the excavation, that the matter be thrown out all round, so as to secure and strengthen the matter first thrown on the outside of the dam.

The depth of the excavation will be found by the following rule. It must at least be excavated 3 feet at a medium below the natural surface of the gravel where the pier stands;

stands ; but if this does not carry down the base of this pier within 2 feet of the level, at which the base of the first pier was fixed, let the depth of the excavation be increased till it is within 2 feet of the former depth.

Method of fixing the foundation, according to the plan.

The excavation being made, as far as is above directed, let the 21 piles, upon which the frame rests, be driven into their proper places : these piles are to be 10 inches heads, and of 6 feet long, supposing the gravel of equal strength with the last, but if there is any reason to suppose it stronger or weaker, the length above mentioned should be increased or diminished. This being done, and the pile heads reduced to a level, lay down the frame thereupon, which I suppose to be ready prepared in the yard, with the tye beams ready fitted with dovetails thereto, and being trenailed down upon the respective pile heads, proceed to drive the sheeting piles, which may be of oak, elm, beech, or fir, as can best be got. I suppose them to be of 6 feet long ; they may be driven plain, as shewn on one side, as was done at *Coldstream Bridge*, but would be preferable if rebated, as shewn on the other half. The choice of the method depends on circumstances ; if, from experience of the other pier, they are like to drive regular, without tearing of the rebates, by meeting with great stones, &c. then they will both drive more regular, and hold firmest by being rebated, but if they are apt to split, then it will be as well to save that time and labour, by making them plain, and more especially so if the difference of expence in workmanship, or hindrance of time in doing it, is likely to be a material object, in that case the rebating may be omitted.

N. B. If driven plain, the breadths of the piles are not material ; but if rebated, narrow piles will enhance the workmanship in preparing. In order to save timber (and especially if fir piles are made use of, it will be much stronger) I propose to groove the piles on both sides, and to nail in the tongue, which, if fir piles, may be of harder wood ; the best proportion for fir piles would be to make the tongue $1\frac{1}{4}$ inch thick, and $1\frac{3}{4}$ broad, to be let $\frac{3}{4}$ into the side where it fastens, and to stand out 1 inch ; but this may be done according as the tools already prepared may suit, there being no need to make new ones on purpose.

The tops of the sheeting piles being reduced to a level with the string-pieces (and spiked thereto as they are driven) the outside must be reduced to a regular breadth, so as to take the notched stones in a line. This being done, the rest of the bearing piles must be driven, beginning with the outside rows, and cut to a level with the top of the string

string pieces; these piles may be of 6 feet, more or less, according as the others are found to go.

The setting must be completed by first underpinning the string pieces and tie beams, as firmly and *equally* as they can, by moderately driving stones under them; and lastly, the other spaces to be set, and well drove down as before; but before they are rammed down, the joints of the setting should be filled by sweeping in dry lime mixed with sand and small gravel, that when drove down the whole may be compact together.

When the pier is got above low water, I would have the matter taken out for 4 feet wide round the pier, down to the level of the top of the notch course, and filled with good lagging as before, standing somewhat higher than the natural bed of the river, and the rest of the space covered with rubble to the sides of the dam.

N. B. I suppose the bearing piles to be sufficiently drove, when it takes 20 blows of a sufficient ram to drive an inch, and the sheeting piling to be so when it takes 40 blows to drive the same quantity; but the sheeting piles should be drove as near to a regular depth as possible.

J. SMEATON.

Austhorpe, April 23, 1767.

P. S. I don't mean to set aside the use of such materials as were prepared according to the plan of last year, unless utterly inconsistent with the present.

P E R T H B R I D G E .

Perth, October 5, 1787.

HAVING this day viewed the bridge of *Perth*, I have the satisfaction to observe every thing relative to it in perfect good condition, the walking path over it excepted; which, from the want of hardness in the stone wherewith it has been laid, is not only much worn, but from the hard pebbles imbedded in the stone itself is become very rough and uneven. For the effectual restoration of this part, nothing would be so completely durable as to remove the present stone-work, and relay the same with *Aberdeen* granite of the same depth as the present. But as the present stone-work of the walking path appears

to me to lay compleatly firm and solid, and being shewn a sample of the *Kingudie* flat paving, which I understand can be procured of any thickness, with parallel surfaces, and also appearing to me to be of a nature sufficiently durable, I apprehend the work may be executed in a substantial manner, as follows :

The stone from *Kingudie* being procured of 4, 5, or 6 inches thickness, as can be most conveniently had, and of such lengths as to make good the whole breadth of the walking path without a joint, but of promiscuous breadths in the direction of the bridge, I would advise to chissel or broach off the upper surface of the present walking path till it comes to a regular height, and then with good mortar to lay down the *Kingudie* flooring, close jointed, upon it, making the joints of the flooring with the best *Pozzelana* mortar ; and in case there is *Pozzelana* remaining in plenty, it would be well to give the mortar wherewith the flooring is bedded an allowance of *Pozzelana*, as suppose, half the quantity ; observing to level the surface of the present mass of stone in such manner as to allow a drip or declivity from the parapet towards the carriage way of about $\frac{3}{4}$ of an inch ; and also to make the breadth of the new flooring about $\frac{3}{4}$ of an inch short of the present breadth, so that the tread of the carriages being taken off from rubbing against the *Kingudie* flooring, it may remain undisturbed being defended by the solid of the present ; and in the same way the walking path may be set with *Aberdeen* granite, provided it is worked to a parallel thickness.

With respect to the paving of the bridge, there is no objection to it as to the structure ; this being merely a matter of convenience, of which those who from their local situations observe and use it can be the best judges. I have only to observe, that the *Aberdeen* granite paving is not only the most durable of any that I am acquainted with ; but, from its roughness, the horses feet are the most steady, and hold the firmest in drawing upon it. The blue whin is the next in degree ; so that where the blue whin is procured upon the place, I cannot think it necessary to send for the *Aberdeen* granite from a distance.

Having viewed the bulwarks that have been erected opposite the *Inch* upon the north-east side of the river, I am of opinion that all such works as cross and intersect the stream of the river, or interrupt the water from gliding freely away, are the means of increasing the stress upon other parts, and therefore, as affecting other properties, should be avoided. When properties want a defence against the incroachments of the waters, it should be by disposing those defences at the foot of the banks, in a direction parallel to the stream, and without interrupting its free course.

CHRISTCHURCH HARBOUR.

The REPORT of JOHN SMEATON, Engineer, upon the harbour of *Christchurch* in *Hampshire*, from a view thereof taken the 20th and 21st of May, 1762.

THE harbour of *Christchurch* is situated in the bottom of a deep bay, formed between the isles of *Wight* and *Purbeck*, and at the mouth of the two large united rivers *Avon* and *Stour*; the passage of which to sea is between two natural points of land not much above 50 yards asunder at low water, within which points the river forms a large inland bay or *basin*, which is properly the harbour or haven of *Christchurch*, and is defended from all winds: with those outlines one would be naturally led to expect a good harbour, capable of receiving a number of large ships; yet, notwithstanding these great advantages, nature has ordered it otherwise.

About a mile or better to the S. W. of the harbour's mouth begins an high point of land, called *Christchurch Head* or *Heads*, for the coast, in running further to the S. W. forms another, which makes a double head, with a small recess or bay between; these heads, as well as a considerable part of the coast extending westward therefrom, stand bold upon the sea, the foot thereof being washed by its waves at high water. Those heads have formerly extended much further into the sea than at present; but being composed of a loose sand, intermixed with some quantity of loose iron stones, the action of the sea upon the foot of these cliffs in time of storms brings it down in great quantities, and is driven by the violence of the seas with wind from S. to S. W. into the bottom of the bay, and there being subject to no counteraction by the opposite winds, it has not only greatly obstructed the bottom of the bay with sand, but has spread itself to a considerable distance from the shore. It further seems to me that the harbour's mouth has formerly been much more extensive than at present, having reached even to the heads; but the sand gradually coming down from the cliffs, and being driven into the haven by the S. W. and S. E. winds, has gradually formed marshes to the N. E. of the high lands, and thereby drove the mouth or channel of the river gradually to the N. E. and again, by the blowing of the sand, left dry at low water, by the S. E. wind, it has formed a range of hommocks or sand-hills, extending from the heads north-eastward to the south point that now forms the harbour's mouth, and has thereby formed a natural bank, part of which separates the basin, now composing the harbour of *Christchurch*, from the sea. The sands thus moving seem to have forced the mouth of the river as much to the N. E.

N. E. as they well can be; and undoubtedly the whole had been long ago shut up, had it not been for the powerful re-action of the fresh waters continually pressing toward the sea from the two rivers aforesaid, which, in wet seasons, as they drain a vast track of country, must be very considerable; and indeed, by the power of such a collection of fresh waters, great things might be done, did not nature throw out another rub in the way, and that is the small flow of the tides at this place.

The great depth of this bay from the main channel tide, the shoalness of the waters occasioned by the sands beforementioned, and the distraction of the current in going different ways round the Isle of *Wight*, I look upon to be the most probable cause of the smallness and irregularity of the tides here. It is not reckoned that the spring tides rise more than from 5 to 7 feet, and the neap tides from 4 to 6; so that it sometimes happens that the neap tides are higher than the springs, depending much upon the course of the winds; the tides are said to be highest with a S. E. wind, and least with wind at N.

I am also informed, that three hours after the regular time of high water, when the main tide in the channel begins to set towards the west, a second tide is formed in this bay, which is generally highest at neap tides, and that the ebb between the two tides is from 8 or 9 inches to 18; which second tide, proving a check of the reflooding power of the land waters, tends to weaken their force in getting to sea.

From the circumstances before described, viz. the flatness of the bottom, the constant motion and increase of the sands, and smallness of the tides, I cannot flatter the inhabitants ever to expect an harbour at *Christchurch* of any great depth or capacity; yet, at the same time, it seems to me capable of great improvement, as will appear from a further description.

Between the points I found a considerable depth of water, but as the width of the channel greatly enlarges without the points, the depth diminishes, and at the distance of about 200 yards an hard gravel shoal is formed, and still further out the bar. From the points to the bar the channel lays E. by S. and from the S. point there runs out a sand, which is dry at low water, and extends from the said point on the S. side of the channel, and in a parallel direction thereto, as far as the bar. This view was taken on the second and third days before the change of the moon, so that the spring tides were scarcely set in.

At this time I found 16 feet water between the points, 4 feet 9 inches upon the gravel shoal, and $5\frac{1}{2}$ water upon the bar, and in the road, which lays about half a mile further

out in the same direction, 16 feet water; the bottom is said to be a strong blue clay, the *Needles* bearing S. E. by S. and *Christchurch Heads* S. W. and just open one with the other. Within the points the channel turns S. W. by the side of the hommacks before-mentioned, and from 16 feet, as it is between the points, comes to 7, 6, and 5 feet.

Christchurch Quay lies about two miles up the river from the harbour's mouth, between which there are the following shoals, beginning at the harbour, viz.

Frisum Shoal, water thereon 4 feet 9 inches, (when $5\frac{1}{2}$ at the bar as above) a loose gravel or shingle 2 feet deep, then turns harder. *Ganbury Shoal*, 5 feet water, bottom soft mud and sand. *Saltmard Corner*, $5\frac{1}{2}$ water, bottom loose gravel or shingle. The *Pick* had 6 feet 3 inches water, and a loose gravel or shingle bottom. There was no other place in the river but what sounded 6 feet or upwards at the said tide.

About 1 furlong from the S. point of the harbour's mouth, towards the S. W. is run out a kind of jetty or pier in a straight line, composed of round lumps of iron stone, which have been brought from the *Heads*; its direction is S. E. and extends from high water mark 256 yards; the *Needles* bear from thence S. E. by S. so that it is land-locked thereby a point of the compass; its top gradually declines from the shore towards the sea, the whole being uncovered at low water, but all or the greatest part covered at high water. Round the end of this pier I found about $7\frac{1}{2}$ feet water, and at about double this distance from the shore about 10 feet, (when $5\frac{1}{2}$ upon the bar) the water being rather better to the N. E. than to the S. W. of this line, the whole bottom being sand, and almost regularly inclining from the shore in the proportion abovementioned.

From information I learn, that the aforesaid pier or jetty was erected in the reign of King CHARLES the Second, and intended for securing a better passage into the harbour, and that for this purpose a cut was made through the hommacks, so as to let the water through the same out of the harbour, and so as to direct its course to the S. W. side of the pier.

This pier, it seems, was intended for the N. E. pier; another pier being designed on the S. W. side of the channel; the other passage in or near the present place was then stopped up with piles, &c. at a considerable expence: this course was maintained for some time, and a deep channel was made by the back waters alongside the pier of 15 or 16 feet deep; but then the matter being deposited, and the force of the land water being spent as soon as it quitted the end of the pier, there still must remain there a bar of the same height as the present bottom; however, as that bottom is at least 2 feet

feet lower than the present bar, it would make at least 2 feet more water into the harbour, which must, of course, prove a very great improvement so long as it lasted. But before a long time had passed it happened that the back waters, not finding a passage to sea sufficiently ready through this new channel, broke over, and forced themselves a fresh passage at the present place, which has ever since continued, and the artificial one was presently shut up by the sea.

From a due consideration of the facts and circumstances above recited, it appears to me as follows.

1st. That from the tendency of the land waters to open and preserve themselves a passage to sea at or near their present place, and from the tendency of the sea to shut up any passage made to the S. W. that the present course is best adapted by nature to be maintained: this is further confirmed by the bottom of the road, which, laying further out in the same direction, is clear of sand; but as the distances from the points to the bar, and from thence to a sufficient depth of water for an entry to a tolerable harbour, to which place two piers ought to be carried out to confine the land waters, and protect the channel from the driving in of the sand, in order to render the same effectual; I say, the great length required for such piers appears to me likely to be attended with too great an expence, added to the great trouble and difficulty in moving the gravel shoal before mentioned, otherwise, in my opinion, this construction would be the least exceptionable.

2d. It appears to me that the grand mistake in the former attempt consisted in constructing the wrong pier first; or in other words in making the channel on the wrong side of it: otherwise, for ought that to me appears, it might have maintained itself an open passage to this day; for had the S. W. pier been built first, or what amounts to the same thing, had this been made the S. W. pier, by making the passage on the N. E. side of it, then it would not have only defended the passage from the sands brought down from the S. W. by the action of the winds and storms from that quarter, but the sea, by breaking over the top of it, would have tended to have deepened the channel on the leeward side; whereas by making the channel on the windward side, it would tend to intercept the sands, and thereby immediately to fill up the channel, had not the superior force of the back water carried it out as fast as brought in; so that I rather marvel a passage was ever this way obtained, than that it should be filled up in the way it was managed.

That this must be the case in some measure, appears from the manner in which the sand now lays contiguous to the pier; for notwithstanding it is within 2 or 3 feet of the

top, yet it lays on the S. W. side at least a foot higher than on the N. E. Indeed I cannot account for a conduct so absurd, otherwise than by supposing the projector imagined the sands to be immovable, with respect to the winds and seas, and not in a travelling state; and observing the strong tendency of the channel to travel to the N. eastward, proposed to stop it by interposing the pier. From this attempt however, though unsuccessful, we may learn how strongly the land waters acted, and what may be done by better management in the same situation.

The direction of the pier S. E. is very good, for vessels may sail in or out with a S. W. wind; it could not be pointed more southerly, so as to give advantage to vessels going in with wind nearer west, than they can now do, without giving advantage to the seas from S. S. E. to roll more directly in, as it would then not land-lock with the needles, but point to the open sea; its situation is also very good, as it stands almost direct in a right line with a reach of the river, and if a vessel should not make the entrance of the harbour, they will have the road to the leeward.

I would therefore advise to construct another pier parallel to the present one, but on the S. W. side thereof, and at the distance of about 240 feet from middle to middle; and when this is carried out from 50 to 100 feet further than the present pier, then to attempt to open a passage through the hommacks, so as to turn the water between them, and at the same time to divert the water from its present course at low water by a catch-dam of rough stones, or by a composition of piles, fascines, stones, &c. by these means a sufficient channel being procured between the two piers at low water, that channel will gradually deepen, and the present channel being deprived of the greatest part of the reflowing power, the sands that are now kept out by the same will begin to close in, and in time will form hommacks so as make an entire stop at high water, and the progress thereof, as occasion may shew necessary, may be helped by art.

By these means the earliest advantage may be taken of the undertaking, and vessels drawing 8 feet water may be brought in at a middling spring tide; and as I would advise the whole to be performed by throwing in of stones upon the same principles as the present pier has been built, the piers may be gradually lengthened, constantly advancing the S. W. pier before the N. E. and it appears, that by extending the piers to double the length of the present, that is, to the length of about 500 feet, there will be $2\frac{1}{2}$ feet more water, that is, there will then at mean spring tide be $10\frac{1}{2}$ feet water, and at neap tides $9\frac{1}{2}$ feet, which will make a very good harbour for small merchant ships, coasting vessels, armed cutters, &c. And as it appears that an extension of about 250 feet procures

cures $2\frac{1}{2}$ feet water, it follows that every 100 feet extent of the piers will procure an additional foot of water, so that the improvement of this harbour may be carried on to any extent, by gradually lengthening its piers, as time, circumstances, the utility of the harbour, and ability to execute, shall suggest.

I do not think it necessary to do any thing to the present pier, till the west pier is carried out as directed, and the water let in between them; but I would advise the west pier never to be left till it has got above high-water. It must at first be made considerably higher than high water, for as I would not advise attempting to dig away the sand for a foundation, whenever the current is turned against it, it will settle very considerably, and unless a good body of stone is originally laid, may settle so much as to make it difficult to add to the mass at top. It is for this reason I would not advise to make the present pier the west pier, for having had a deep channel on the west side of it, the matter thereof on that side had got sufficiently compacted to a due depth; but was the channel made on the east side, the foundation being there shallow, would be undermined, and occasion it to settle afresh, and require a large addition of materials to make it up to the same height.

As the tides are said to rise from 4 to 7 feet upon the bar, $5\frac{1}{2}$ will be the mean, which was what I observed; and as I found no part of the river between the harbour and the town of *Christchurch*, but what, at that time, sounded 6 feet and upwards, except the shoals before specified, all which are composed of soft and loose matter, and of no great extent, I look upon it as very practicable, by dredging, to make good a 6-foot channel from the harbour to the town quay, at a mean tide, which will be very sufficient for all kinds of lighters and small craft. This may possibly be done by the river itself, whenever it gets a more sufficient outlet to sea; and much more cannot be expected, without a very considerable expence.

The iron stones now laying upon the sands under *Christchurch Heads*, are a very proper material for the construction of the works abovementioned; but I fear they will not be found in sufficient quantities, if not, rough unformed stones may be brought from *Pevel Point*, or *Portland*, the cap of which is refuse, and will answer as well as finest stone.

I have added a sketch of the harbour, as it appeared to me on view, and the measures above specified, wherein what is done in red is the proposed works.

As this is a work that depends much upon circumstances, it is not easy to make a tolerable estimate; yet, to give all the satisfaction in my power, the best I can judge of it is as follows.

ESTIMATE for the works proposed to be constructed at the harbour's mouth, according to the preceding scheme.

	£.	s.	d.
I suppose the great S. W. pier will, at a medium, take 224 cube feet of matter in each foot running, and for 1500 feet 336,000 feet; this, allowing 12 feet of iron stone to the ton, will produce 28,000 tons; and supposing this to be brought from the heads, and laid in place at 2 s. per ton, will come to	2800	0	0
For the prolongation of the north-eastern pier 210 yards, I suppose 168 cube feet per foot running may be sufficient, and this for 630 feet is 105,840 cube feet, which will make 8820 tons, at 2 s.	882	0	0
For making a cut through the hommocks, at a medium, 66 yards long, 66 yards wide, and 3 yards deep, will contain 13,068 cube yards, which at 4 d. comes to 217 l. 16 s. but as some work will be required in clearing away some of the sand between the piers, till a passage can be procured, if for this service we reckon 82 l. 4 s. the whole will be	300	0	0
For covering the border of the new cut with stones, so as to prevent its washing, and thereby to prevent the water from getting part behind the piers; this, at a medium, being faced up half a yard thick, will take about 1500 tons, at 2 s.	150	0	0
For making a catch-dam to force the water of the haven through the new cut and between the piers, at low water; this, if constructed wholly with rubble, and being supposed, at a medium, to contain 70 feet cube per foot running, this, for 720 feet in length, will require 4200 tons, at 2 s.	420	0	0
To incidental expences, at 10 per cent.	455	0	0
	5007	0	0

N. B. As the quantities are given, if the iron stone can be moved cheaper than above set down, the saving will be in proportion; but if the quantity above specified cannot be got from the heads, what will be necessary to be brought from *Purbeck* or *Portland* will be at an advanced price, and will at least, I suppose, come to 5 s. per ton; but it is to be noted, that one ton of this stone makes 16 feet.

Austhorpe, August 13th, 1764.

J. SMEATON.

ADLING FLEET LEVEL.

The REPORT of JOHN SMEATON, Engineer, upon a view and observation taken of the level of *Adling Fleet*, &c. from a plan of the said level, taken by Mr. CHARLES TATE, Surveyor, in the year 1764.

IN the year 1755 I was employed by the owners of the manor of *Haldenby* to take a general view of this level, in order to form a scheme for the drainage thereof; and finding that the great defect laid in the drains and out-fall clough, I made a report, shewing how these defects were to be remedied, to the general advantage of the whole, as well as *Haldenby* in particular, as will more fully appear by reference to the said report, not supposing at that time that the proprietors would be willing to be at the charge of getting an act of Parliament, in order to enable them to make new drains in any more proper direction.

The present view and report being made at the general request of the principal proprietors of the said level, who not scrupling the expence of an act of Parliament, in case it should be requisite, I have taken a further and more minute, as well as unconfined, view of the whole; and though from hence it appears that a more eligible course of drainage offers itself than the old one formerly proposed, yet it also appears, that had my former directions been put in effectual execution, the proprietors would have found no occasion for a second application, and would have reaped the benefit of the improvements during the intermediate time.—I also find the coincidence of the levels taken then, and now, surprisingly great, considering the badness of the season then, and that the greatest part of the low grounds were then under water, there being but 2 inches difference between the fall from the low part of *Haldenby Common* (which is the lowest land) and the floor of our fleet clough, as taken then and now, as will appear by comparison of the former observations with the present; but as the latter observations were made under more favourable circumstances, and with more accurate instruments, I shall chiefly rely upon my last observations, which are as follow.

Rise from low-water mark at the <i>Ouse</i> , September 1764, to the floor of <i>Hackenfyke</i> or <i>Ousefleet</i>	Ft.	In.
<i>Clough</i> , - - - - -	3	0½
Rise from the floor of the <i>Clough</i> to the surface of the water in the drain at <i>Coat's Bridge</i> ,	4	9
Rise of water from low-water mark at the <i>Ouse</i> to <i>Coat's Bridge</i> , - - - - -	7	9½

Many parts of the bottom of *Hackenfyke Drain* are not more than 14 inches below the level of the surface of the water at *Coat's Bridge*.

Rise

	Ft.	In.
Rise from low water at <i>Trent Fall</i> to the surface of the water in the drain at <i>Coat's Bridge</i> ,	9	5
Fall of the <i>Ouse</i> from <i>Hackenfyke Clough</i> to <i>Trent Fall</i> ,	1	7½
<hr/>		
<i>N. B.</i> The rise of the different points of the land above the water at <i>Coat's Bridge</i> , is inserted in circles upon the map.		
From <i>Coat's Bridge</i> , for the run of the water through the drains, I allow to the stagnant water on <i>Haldenby Common</i> a rise of	0	2
<i>N. B.</i> The depth of this stagnant water was in general about 9 inches; from this stagnant water to <i>Green Bank</i> , the water along <i>Eastoft Drain</i> was in general stagnant; but the sum of the rise taken at different stoppages amounted to	0	3
Rise from thence to the mean surface of the land near the head of the division drain, between <i>Eastoft</i> and <i>Whitgift</i> , on the north side of <i>Green Bank</i> ,	0	7
<hr/>		
Rise from <i>Coat's Bridge</i> water to the general surface of the land on the north side of <i>Green Bank</i> ,	1	0
Rise from the general surface of the lands on the north to the surface of the water in <i>Eastoft Drain</i> , south of <i>Green Bank</i> , which were upon a level with the lowest lands there,	1	2½
<hr/>		
Rise from <i>Coat's Bridge</i> to the surface of the lowest lands in <i>Eastoft</i> , south of <i>Green Bank</i> ,	2	2½
<hr/>		

Consequently,

	<i>Ouse</i> at <i>Hackenfyke Clough</i> .	<i>Trent Fall</i> . Ft. In.
The lowest lands in <i>Haldenby</i> above low-water mark at	7 2½	8 10
The lowest lands in <i>Eastoft</i> and <i>Whitgift Moors</i> , north of and contiguous to <i>Green Bank</i> ,	8 9½	10 5
The lowest lands in <i>Eastoft</i> , south of <i>Green Bank</i> ,	10 0	11 7½

As I found no considerable quantity of water remaining upon the tract of country under consideration, except upon *Haldenby Common* and adjacent places, it follows from hence that, agreeable to my former observations, *Haldenby Common* is the lowest part thereof, and consequently what will drain this part, will, of course, drain all the rest; and since this part lays 4 feet 2 inches above the floor of *Hackenfyke Clough*, it may be wondered why 9 inches water should remain thereon in a dry season; but as it also appears, that many parts of the bottom of *Hackenfyke Drain* lay but 14 inches below the water of *Coat's Bridge*, it will of consequence be not more than 7 inches below the land surface of *Haldenby Common*; from which if we take 3 inches for the declivity of the water, to produce a sensible run to the place of obstruction, there will remain only 4 inches for the depth of water upon the bottom of the drain, which is so small a body that the water cannot be run off in the course of the summer, if it should prove showery; nor otherwise, till it is evaporated by the sun and winds, which are the only means by which this piece of ground can be drained, as things are now constituted.

I thought

I thought proper more particularly to remark this fact, because it at once points out the cause and cure of the evils that attend the whole level.

That *Haldenby Common* admits of drainage by *Hackenfyke Clough*, even as it now stands, appears hence.

	Ft.	In.	Ft.	In.
The whole fall from the surface thereof to the <i>Clough</i> floor being	-	-	4	2
Suppose 6 inches thickness of water to go over the first floor,	0	6		
The surface of the water being reduced 2 feet within soil, makes a complete drainage,	2	0		
	Sum		2	6
Remains the declivity of the water's surface in the drains between <i>Haldenby Common</i> and the <i>Clough</i> ,			1	8

The distance by the course of the drains, straightened according to A B G H I e f, will be 3 miles $2\frac{1}{2}$ furlongs nearly, which is full 6 inches per mile, which is within the limits of a good drainage.

Hence it appears, beyond a doubt, that the whole level may be drained by *Hackenfyke Clough*, as it now stands, provided drains of proper depth and capacity were made correspondent thereto; but as that *Clough* lays full 3 feet higher than low-water mark, it is capable of being laid so much lower, and the drains being proportionably deepened correspondent to this lower situation: this would occasion so considerable a descent, as to run off the waters of the greatest downfalls as fast as they came down, without danger of overflowing any of the lower grounds, which might sometimes be the case, was the *Clough* continued at it's present height*.—Let us now see what fall will be obtained, upon a supposition that the *Clough* floor was lowered 3 feet.

The whole fall from the south end of the moors contiguous to <i>Green Bank</i> , to the present <i>Clough</i> floor, is	Ft.	In.
	5	9
And the <i>Clough</i> floor being lowered 3 feet, would make,	8	9
The distance by the course of the drains straightened, according to the letters A B C D E F h, will be not quite, but near upon five miles; and supposing we allow a descent of 1 foot per mile, which is very ample and sufficient for any purposes of drainage, the whole descent would be,	Ft.	In.
	5	0
And allowing for the thickness of water going over the floor,	0	6
Sum to be taken from the whole fall,	5	6
Remains the quantity that the water will be reduced within soil, at the most remote low places,	3	3

* N. B. This would be prevented by gates being erected, as mentioned in my former Report.

N. B. This is 1 foot 3 inches more than necessary, and will be more at all nearer distances, as further appears thus :

	Ft.	In.	Ft.	In.
The fall from <i>Haldenby Common</i> to the <i>Clough</i> floor, if laid 3 feet lower, will be	-	-	7	2
The descent for 3 miles $2\frac{1}{2}$ furlongs, at 1 foot per mile, will be	-	3	3	$\frac{1}{2}$
The water over the floor,	-	0	6	
The sum deduct from the whole,	-	-	3	$9\frac{1}{2}$
And there remains for the reduction of the water within soil at <i>Haldenby Common</i> ,	-	-	3	$4\frac{1}{2}$

Hence it appears, that was *Hackenfyke Clough* floor laid lower by 3 feet, and the drains properly adapted thereto, that it would be as effectual as could be desired.

It next comes in place to enquire, whether new drains in a different direction, and to a different out-fall, may not be more eligible than the former ; and from inspection of the country it appears, that the natural course of drainage tends from *Haldenby Common* towards *Trent Fall*, which is undoubtedly the lowest ground ; and it also appears from the levels that there is a greater fall thither than to the *Ouse* at *Hackenfyke*, by 1 foot $7\frac{1}{2}$ inches ; it also appears by the plan, that the distance, according to the course of the new proposed drain, *a b c d e f g h*, is rather more than $5\frac{1}{4}$ miles, which is somewhat more than $\frac{1}{4}$ of a mile more than the former, which in this case is inconsiderable : if therefore the drainage to *Hackenfyke Clough* is as compleat as can be required, when laid 3 feet lower than at present, it will be still more unexceptionable when laid at the same depth at *Trent Fall*, for as it will then lay 1 foot 8 inches above low-water mark, it will run a greater length of time at each tide, and therefore the drains, after making proper allowance for the difference of distance, may be of less width than would be required at *Hackenfyke* to be of equal effect.

The falls will then stand as follows :

From the surface of the moors north of <i>Green Bank</i> , to the floor of the sluice at <i>Trent Fall</i> , laid 3 feet below that now at <i>Hackenfyke</i> ,	Ft.	In.
	8	9
	Ft.	In.
Thickness of water over the floor,	0	6
Fall of the water $5\frac{1}{4}$ miles, at 1 foot per mile,	5	3
The sum to be deducted from the whole,	3	9
Leaves for the reduction of the water within soil at <i>Green Bank</i> ,	3	0
Again. From the surface of the land of <i>Haldenby Common</i> to the floor of the sluice at <i>Trent Fall</i> ,	7	2
Thickness of water over the floor,	0	6
Fall of the water according the course <i>a b c d e f g</i> , $3\frac{1}{2}$ miles, at 1 foot per mile,	3	6
The sum to be deducted from the whole,	4	0
Remains the reduction of water within soil at the lowest part of <i>Haldenby Common</i> ,	3	2
		This

This reduction would drain even *Plumb Groves* and *Robinson Deep*s, was it not advisable to reserve those undrained for watering cattle, for which purpose it will also be necessary to have land-doors to the outfall clough or sluice, to pen the water at dry seasons, and also at some other places; but as those will be private works it will be needless to insist thereupon. The proper widths, depths and dimensions of the drains and sluice are contained in the following Estimate. The course relative to *Trent Fall* are coloured yellow, those to *Hackenfyke* red.

This level is very well circumstanced with respect to barrier banks. The only ones that appear necessary to be repaired, on account of the general undertaking, is the south wing of *Green Bank* and *New Bank*, the particulars of which are contained in the Estimate. I find the marks left by the floods last winter, upon the south side of the *Green Bank*, to be 3 feet 11 inches above the surface of the lowest grounds there, that is, 6 feet 10 inches above the lowest grounds of *Haldenby*; and as this body of water was brought hither by a general overflowing of the level of *Hatfield Chase*, occasioned by the breaking of the banks of the river *Idle*, it would in consequence have laid almost the whole tract now under consideration under water, if it had failed. It therefore plainly appears that this bank should not only be continued as a barrier, but strengthened and prolonged, as specified in the Estimate, for the safety of all the lands laying north thereof.

It comes now under consideration how far the drainage of the land of *Eastoft* south of *Green Bank*, into the drains proposed for this level north of *Green Bank*, can be complied with, with safety to the latter: and I am of opinion it may be done with perfect safety, provided the communication through *Green Bank* be made by a tunnel not more than 10 inches square, with a shuttle or stop sluice thereupon; for had such a tunnel been open and running during the flood of last winter, had also the drains and outfall clough, specified in the following Estimate, been then made, I am of opinion it would have been carried off as fast as it was uttered, without overflowing the level. But to take away all scruple, I would propose to lay the running of this tunnel under the following restrictions.

1st. It shall always be kept shut whenever the grounds to be drained thereby are overflowed by the waters from *Hatfield Chase*, or any other foreign waters, overtopping its barrier banks, and to continue shut so long as the water thereupon has any communication with any such foreign waters.

edly. That it shall be kept shut at all other times, when the water in the mother drain rises within 9 inches of the surface of the low part of *Haldenby Common*, or within 6 inches of the general surface of the lands laying north of *Green Bank*, which may be ascertained by setting up stones or marks for that purpose.

The continuing of the barrier of this part of *Eastoft* beyond the limits specified in the Estimate, the internal drains, erections, and maintenance of the tunnel of communication, I look upon to be private works, respecting this part of *Eastoft* Lordship, and therefore not comprized in the Estimate; and as this scheme proposes nothing more than the carrying the mother drain to the boundary of each Lordship, so as to give the waters thereof a proper outfall, all other drains and internal works are considered as private works, and to be done at the particular expence of the respective proprietors.

ESTIMATE for a Drainage, by a new course, to *Trent Fall*. The floor of the sluice to lay 3 feet lower than the floor of the present Clough at *Hackenfyke*, that is, about 1 foot 8 inches above low water at *Trent Fall*, the sluice to be 10 feet water-way, the drain to be 10 feet bottom, to rise from the Clough towards *Green Bank*, which will be at the rate of 10 inches per mile.

	£.	s.	d.
To digging the pit for the clough or sluice, 19 feet deep, 35 feet mean width, and 100 feet mean length, containing 2463 cube yards, at 4d.	41	1	0
To 94 yards in length, from the <i>Trent</i> to <i>a</i> , exclusive of the sluice-pit, 15 feet deep, 10 feet bottom, 50 feet top, containing 4700 yards, at 3d.	58	15	0
From thence to <i>b</i> , 387 yards, 12 feet deep, 10 feet bottom, 42 feet top, containing 13416 yards, at 3d.	167	14	0
From thence to <i>Hoggard's Lane</i> , the end of <i>Long Dyke Bank</i> , at <i>c</i> , being in length 1150 yards, being 10 feet bottom, 36 feet 8 inches top, and at a medium 10 feet 3 inches deep, containing 30796 cube yards, at 3d.	384	19	0
From thence through the rising ground of <i>Adlingfleet</i> , by the side of <i>Long Dyke Bank</i> , to <i>d</i> , length 550 yards, 10 feet bottom, 36 feet top, and mean depth 9 feet 7 inches, containing 13628 yards, at 3d.	170	7	0
From thence to the north end of <i>Willow Bank</i> , <i>e</i> , 2550 yards long, 10 feet bottom, 29 feet mean width at top, and 8 feet 1 inch mean depth, containing 44989 yards, at 2½d.	468	12	8½
From thence to <i>Green Bank</i> , by the letters <i>a f g h</i> , being in length 5496 yards, at a medium 8 feet bottom, 18½ feet top, and 5½ feet deep, containing 42234 yards, at 2d.	351	19	0
To making the branch drain <i>k l</i> for communicating the waters of <i>Whitgift</i> low grounds with the main drain, being 690 yards long, 5 feet bottom, 13 feet top, and 4 feet deep, containing 2760 yards, at 1½d.	17	5	0
Carried forwards,	1660	12	8½

	£.	s.	d.
Brought forwards,	1660	12	8½
To repairing and strengthening <i>New Bank</i> , by way of a barrier, to defend the whole level against <i>Reednefr Common</i> , so as to have 12 feet base, 4 feet top, and 4 feet high, containing 2500 yards in length, and in the whole 8889 yards, at 1½ d.	55	11	1½
To repairing and heightening <i>Green Bank</i> , from the elbow southward, with an addition of 2 yards per yard running at a medium, being 1260 yards long, containing 2520 yards, at 2 d.	21	0	0
To extending <i>Green Bank</i> about 100 yards further south, so as to render the same effectual, to be 12 feet base, 4 feet top, and 4 feet high, containing 355 yards, at 1½ d.	2	4	4½
Spade work	£. 1739	8	

Building.

To building a new sluice, of brick with stone facing, at <i>Trent Fall</i> , to be 10 feet clear water-way, including temporary dams, drainage of water, filling in the ground, and opening the sluice	500	0	0
For a road bridge, of brick, at <i>Hoggard's Lane</i>	40	0	0
To a ditto at <i>Cow Pasture Lane</i>	30	0	0
To a bridge for cattle, the middle of <i>Haldenby Common</i>	15	0	0
To a road-bridge, at the road leading to <i>Whinsgate Bank</i>	30	0	0
To a cattle-bridge, over the main drain, to communicate the two parts of <i>Ousefleet Common</i> ,	10	0	0
To a ditto, over the branch drain	5	0	0
Building	£. 630	0	0

Abstract.

Spade work	1739	8	2½
Building	630	0	0
Supervising and contingencies, at 10% per cent.	237	0	0
Total,	£. 2606	8	2½

The quantity of land used in this undertaking.

	Cut.			Covered.		
	A.	R.	P.	A.	R.	P.
In <i>Adlingfleet</i> , <i>Trentfield</i> , and high grounds from <i>Trent</i> to point <i>d</i> ,	5	3	16	11	2	32
<i>Adlingfleet</i> low ground, from <i>d</i> to <i>e</i> ,	5	0	16	10	0	32
<i>Willow Bank</i> from <i>e</i> to <i>f</i> , there being space enough for the cut	2	1	16	4	2	32
From <i>g</i> to <i>m</i> , across <i>Haldenby Common</i>	14	0	0	8	0	0
Through <i>Ousefleet Moor</i> , &c. from <i>m</i> to <i>b</i> , at <i>Green Bank</i>	0	2	20	1	1	0
The branch drain to <i>Whitgift Moor</i> , from <i>k</i> to <i>i</i> ,						

Abstract of the Estimate by way of *Hackenfyke*.

The drainage by *Hackenfyke* being estimated in the same particular manner, and the main drain being made 11 feet bottom, to the point *B*, near *Coat's Bridge*, in order to be an equivalent to the greatest length of time of running at *Trent Fall*; and being made from thence in two branches, one along the course *C, D, E, F, b*, which will drain *Ousefleet, Whitgift*, and part of *Eastoft*, and the other by the course *B, G, H, I, e, f*, which will drain *Adlingfleet, Fockenby, and Haldenby*, and also a second branch from *C*, by the *Folly to Bought Gate*, to make a proper out-fall for *Eastoft* waters.

	£.	s.	d.
The Spade Work	1833	4	10
Building	645	0	0
Contingencies, at 10 per cent.	248	0	0
Total,	£. 2726	4	0

Land used in this Undertaking.

	Cut.			Covered.		
	A.	R.	P.	A.	R.	P.
From <i>Ouse</i> to <i>A</i> ,	1	1	12	2	2	24
From <i>A</i> to <i>C</i> ,	8	0	35	16	1	30
From <i>C</i> to <i>Green Bank</i>	3	1	20	6	3	0
From <i>B</i> to <i>e</i>	2	1	20	4	3	0
<i>Willow Bank, e</i> to <i>f</i> , land enough for a cut,	-	-	-	2	0	0
Branch from <i>C</i> to <i>Bought Gate</i>	1	0	0	2	0	0
	16	1	7	34	2	14

N. B. If *Hackenfyke Clough* was made use of, as long as it will stand in it's present form, and the drains dug of a proper width to admit of their being carried to a proper depth, when that Clough shall be obliged to be rebuilt on account of repairs, and lowered to the proposed depth,

	£.	s.	d.
The Spade Work will then come to	1691	3	10
The Building to	145	0	0
Contingencies to	183	12	0
	£. 2019	15	10

And in case *Ousefleet Clough* was to remain as it does, without intention of lowering the same, the expence of proper drains, &c. suitable thereto, would amount to 1636l. 5s. 0½d.

J. SMEATON.

Louth, December 31 1764.

DRIFFIELD BECK CANAL.

ESTIMATE for making a navigable Canal from *Driffield Beck* to a place called the *Townsend*, near *Skerne*, to be 16 feet at bottom, and 4 feet deep of water, with batters or slopes according to the nature of the ground.

FROM <i>Driffield Beck</i> to the beginning of <i>Lewcop</i> pasture, being $15\frac{1}{2}$ chains length, mean depth 6 feet 5 inches, batters 1 to 1, the mean width at top will be 28 feet 9 inches, containing 5432 yards, at 2 <i>d.</i>	£. s. d.
	45 5 6
Cross <i>Lewcop</i> pasture to the low corner of the <i>Holmes</i> , length 12.3 chains, mean depth 8 feet, the batters as 3 to $3\frac{1}{2}$, the mean width at top will be 34 feet 9 inches, the solid contents 6110 yards, at 3 <i>d.</i>	76 9 9
From the low corner of the <i>Holmes</i> to 19.6 chains up the same to the point 1 in the map, mean depth will be 11 feet $8\frac{1}{2}$ inches, and being of a marly nature, the batters as 3 to 4, the mean width at top will be 47 feet 2 inches, the solid contents 17712 yards, which being hard to dig may come to 4 <i>d.</i>	295 4 0
Cutting to the middle of the <i>Holmes</i> ,	416 19 3
To enlarging the canal to 28 feet bottom, for 60 yards at the head, so as to take 2 boats in breadth and 3 in length, for convenience of unloading at warehouses, being there $12\frac{1}{2}$ feet deep,	16 13 4
To drainage of water, supervising, and contingencies,	60 0 0
To the middle of the <i>Holmes</i> ,	<u>493 12 7</u>

From the middle of the *Holmes*, to the *Townsend*, upon a dead level.

To carrying on the cut from the middle of the <i>Holmes</i> to the top of the <i>Pigbill</i> at P, being being 31.10 chains long and 18 feet mean depth, the batters being 3 to 4, the top width will be 64 feet, the solid contents 54720 yards, at 4 <i>d.</i> $\frac{1}{2}$.	1026 0 0
From thence to the <i>Townsend</i> , being 23.5 chains length, mean depth 20 feet, the batter 3 to 4, the top width will be 72 feet, and the solid contents 53079 yards, at 5 <i>d.</i>	1105 16 3
	<u>2131 16 3</u>

ESTIMATE for carrying the navigation to the *Townsend* by a lock.

To the middle of the <i>Holmes</i> , the cut as before,	416 19 3
A lock there to rise 10 feet,	600 0 0
To cutting from thence to the top of <i>Pigbill</i> 31.1 chains, at a medium 8 feet deep, batter 3 to $3\frac{1}{2}$, the top width will be 34 feet 9 inches, the solid contents 15443 yards, at 3 <i>d.</i>	193 9 9
Carried over	1210 9 0

	Brought forwards	£.	s.	d.
To cutting from top of <i>Pigbill</i> to <i>Townsend</i> , being 23.5 chains, mean depth 11 feet, batters as 3 to 4, the width at top will be 45 feet 4 inches, the solid contents 19399 yards, at 3 d. $\frac{1}{2}$		1210	9	0
To making the dock as before,		282	18	0
To bringing the water over the moor, suppose		16	13	4
To supervisal and contingencies,		15	0	0
		150	0	0
	Total	1675	0	4

A DESCRIPTION of this plan, with a comparative calculation of its abilities with the present work, here follows :

1, 1, 1, &c. represent the different parts of the frame-work, 2, 2, 2, &c. the parts of the water-wheel; 3, 3 its starts, of which more hereafter; 4 the main shafts ends; 5, 5 the parts of the spur-wheel; 6 the wallowers; 7 the crank; 8 the crank rod, which communicates with the sub regulator; 9 and 10 the communicating rod between; 9 the sub, and 11 the top regulator; 12, 12 the arch heads to the top regulator, to enable the buckets to make a perpendicular stroke, thereby enabling them to last much longer, go looser leathered, which will chamber or wear the barrels less, and lose less water. B. B. The chains to the bucket or piston rods; 14, 14 the bucket rods; 15 the bucket at the end of its rod in the section of the engine; 16, 16 and 17, 17 the face view of an engine together.

Now whereas the circumstances attending these works, being almost peculiar to themselves, it requires, in order to render them more efficacious and serviceable, a particular or peculiar application; for though there are many stream and current mills, yet they go with a much more uniform motion, having nearly a certain quantity of back water, or strength of current; but as both these articles are so varying at these works, it requires a varying application of machinery, which is performed as follows: supposing the wheel to be at work with the greatest strength of tide, and going three turns per minute, then the sub regular to 9 has its fulcrum or center of motion at *a*, which being 12 feet distance from *b*, where the crank rod lifts 2 feet 6 inches, and *b* being 6 feet from *c* in the sub, and *d* in the top regulator, both lift 2 feet 9 inches; and as *d* is 10 feet distant from its center of motion *e*, and 3 feet from *f*, the chains center, and that of the barrel, therefore it makes 4 $10\frac{1}{2}$ stroke in the barrel; and when the wheels are at work with a great quantity of water, and move at a slow rate, yet there is the sufficient momentum or force

force to raise much water ; that force being always as the quantity of water multiplied into the velocity, so that if there be three times the depth in water, and but one third of the velocity, that is, at the strength of the tide, nearly as much water may be raised as at strength of tide, in order to attain which, it is necessary the engines should make a stroke proportionably longer, as they move fewer times, which will be obtained by moving the center of motion *a* to *aa*, then as *aa* will be 5 feet 6 inches from *b*, upon the crank-rod lifts 2 feet 6 inches, and *b* being 6 feet from *c*, therefore *c* and *d* in the top regulator are both lifted 5 feet $2\frac{3}{4}$ inches, and *f* the chain, and, consequently, the rod 6 feet $10\frac{1}{2}$, which is such a stroke made in the engine, which compensates in a great measure for the slowness of motion in the wheel ; and all this is done in the most simple and lasting manner, by the application *g* at the end of the sub-regulator 9.

Now the comparative quantity of water raised by the present, and what might be raised, are as follows.

Having considered that though there are rules in mechanics for finding the quantity of water passing by in a given time, in a given section, by knowing the height of the water, but as that is very difficult but where the back water is very inconsiderable, and that the velocity of the water at its surface might be obtained, I rejected both in this case, and noted, that the three-ring wheel, at the strongest working, has gone $6\frac{2}{3}$ turns per minute, which is nearly 25 feet diameter, and the new wheel in the same time made $5\frac{1}{3}$ turns per minute, which is nearly 30 feet diameter ; the whole space passed through in the minute, by each wheel, being 495 feet, this, with their charge of work on them, which must impede the water's motion at least $\frac{1}{4}$; therefore, if neither had been doing work, the water, by going $\frac{1}{4}$ quicker, would have passed through a space of 619 feet per minute, which multiplied into 5 feet, which is about the depth the wheels go the strongest at, and the product in 12 feet from the width, gives 37140 cubic feet of water expended on the wheel per minute, which is 3612 hogheads ; now as the wheels revolution vary as $6\frac{2}{3}$ to $5\frac{1}{3}$, therefore the quantities raised must vary in like proportion, that I will reason upon the greatest quantities raised, which is $15\frac{1}{2}$ hogheads per minute. Now as the difference or head of water is obtained by knowing the water's velocity, and that being known as above to be 619 feet per minute, it results that the acting head to produce that must be 2 feet nearly ; and I will suppose that the average height of all the water then raised by the four engines on the wheel did amount to 100 feet, that is what some part of it might be raised higher, other like part discharged as much lower, and as 2 feet, the acting head, is contained five times in the height, we will suppose each hoghead to be one pound ; then suppose 3612lb. (or hogheads) expended on the

wheel each minute, to be laid upon one end of a lever at 1 foot distance from the center, it is evident it would keep in equilibrio 72lb. at the other end, which is supposed to be 50lb. on the other side of the center, which 72 should be the number of hogheads of water the wheel should keep suspended on the engines, it being the 50th part of the water expended, and fluids act in resisting in this kind as solids, on levers; but, to allow amply for friction, &c. and to give the part of the machine sufficient motion, I will suppose, that nearly $\frac{1}{3}$ of the 72 might be raised, (for in good machines, under favourable circumstances, $\frac{1}{3}$ of the 72, or 54 hogheads, might be raised) which will be 24, and, according to my expectation, something more than that quantity, viz. 27 hogheads per minute, for and by the following reasons: as the wheels floats are now no more than from 15 to 24 inches wide, they can produce no greater effect by their resistance than in proportion to their surface, for all the water that might be acting against them, extra to their present dimensions, goes over, rather to the impediment of the wheel than not, whereas was this width increased, the power of the wheel would be increased likewise to a certain measure, but not if the other parts remained the same as now, for as the wheels go now nearly the same pace as the water, therefore it is necessary to slacken the wheels motion, and increase the engines strokes, to resist the running water more, and thereby a proportionably greater quantity of water would be raised: then the starts 3.3, should be thus constructed; they should all stand out 3 feet from the ring, each other having the boards only up to the ring, as may be seen by inspection, and the others having the boards within to 5 feet from the starts end, as shewn: the method for doing them cheapest, most lasting, and serviceable, is to make the starts pretty wide, cut a slit in the middle, and slip the boards down it, and the whole is secured with a small bolt in the short, and two in the long ones, without iron plates; and up against each arm of the water-wheel to put boards 6 feet from the starts end, by this method the wheel will be impeded getting into water less than if the starts were all 5 feet long, and the boards as broad, and nearly the same effect produced.

Now by this provision, the wheel, when going so slow as 3 turns per minute, will so resist the water as to give it an opportunity to act so powerfully as to work 6 engines of seven-inch barrels in this manner at strength of tide, 3 turns the wheel, the wallowers going 3 to the wheels 1 makes 9, and the sub-regulator moving on the center *a*, will produce 4 feet $10\frac{1}{2}$ inches stroke, which multiplied into the 24 barrels will produce 27 hogheads nearly per minute; and in less strength of tide, for some time before and after high water, the wheels will go from 1 to 2 turns per minute, by means of the large surface of floats, I will call it $1\frac{1}{2}$ turns, and then the sub-regulator will move on the center

center *aa*, which will produce 6 feet $10\frac{1}{2}$ inches stroke in the engine barrels, and that in the 24 barrels will give 19 hogsheads per minute.

3 rings at $6\frac{3}{4}$ turns rise 15 hogsheads per minute.	This design at 3 turns to rise with 4 feet $10\frac{1}{2}$ inches stroke, 27 hogsheads per minute.	Ditto at $1\frac{1}{2}$ 6 feet $10\frac{1}{2}$ inches stroke, 19 hogsheads per minute.
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The following is an examination of the said engine, in answer to the above.

Examination by JOHN SMEATON of a design for a Water-Engine, communicated by
Dr. BIRCH.

This design, though not so mentioned, appears evidently intended for *London Bridge* water-works, and therefore as such I shall consider it; and though the unknown inventor of the design has shewn evident marks of genius, and a laudable attempt of improvement, yet as I cannot agree with him in the whole of his reasoning about it, I think it necessary to give my opinion with that freedom that becomes me in a matter wherein I am consulted, and therefore have a right to expect that what I may say will not be considered as the effects of a desire to criticize, but to do justice, where my opinion is desired in the way of my profession.

In the first place, I agree with the inventor in the use of arches and chains at the end of the regulator, having ordered the like in the engine lately erected for the *West Ham* Company at *Stratford*.

2d. I also agree with him in thinking the circumstances of these works are so peculiar to themselves as to require peculiar applications, in order to bring them to perfection, and that it is to be wished that means could be found out by which the load could be occasionally varied, in proportion to the variations of velocity and power, without rendering the engines complex, and more liable to be out of order. I also agree with him, that by means of a moveable center, to what he calls a sub-regulator, the stroke of the engine may be varied, and therefore the power of the engine in the same proportion; but I can by no means agree with him in the use to be made of this machinery; he supposes that when the tide is high, and the current moves slow, that the body of water being then great, the superior quantity will be equivalent to the want of velocity, so that if there be 3 times the depth in water, and but $\frac{1}{3}$ of the velocity, that is at the strength of tide, nearly as much water may there be raised; as at the strength of tide.

But had the inventor computed the head or acting column of water necessary to produce $\frac{1}{2}$ of the velocity, by the same rules that he finds 2 feet necessary to produce the velocity of 619 feet per minute, he would have found $\frac{1}{2}$ of 619, viz. 206 feet per minute, produceable by a head or column $2\frac{3}{4}$ inches, which is only $\frac{1}{2}$ of 2 feet, it being well known that the square of the head is as the velocity. Hence it appears, that as the acting column is only $\frac{1}{2}$ of the height, the impulse or pressure upon the same quantity of surface of float-board will be $\frac{1}{2}$ also; and even if we suppose the surface acted upon to be increased in proportion to the depth of water, which is not the case, (in the construction before me) the whole impulse or pressure upon the wheel can be only $\frac{1}{2}$ of what it would be at strength of tide; so that if the wheel is loaded as here proposed, near high water more than at strength of tide, in the proportion of 4 feet $10\frac{1}{2}$ inches to 6 feet $10\frac{1}{2}$ inches, which is as 5 to 7 nearly, it is very probable that the wheel, instead of doing *nearly as much as at the strength of tide*, would stand quite still, and the benefit of the slow motion, that would otherwise take place, quite lost: in short, it is like a horse moving slow with his load in consequence of having carried it far, and being wearied therewith, to load him harder in order that the greater burthen may compensate for the slowness of his motion. It therefore plainly appears, that if any good is to be expected from this sliding motion, it must be by adjusting the longest stroke to the strength of tide, that as the tide grows weaker the stroke may be shortened, and the power of the engine adapted to the power to move it.

In regard to the machinery of the sliding center, as it is not perfectly made out, I am enabled to say the less upon it; but in an engine that works both ways, that is, lifts up as much as it pulls down, any shake in the center work will be very detrimental to its motion, and occasion it to be frequently out of order; and further I conceive it difficult so to contrive it as to be, and keep lastingly steady, especially as in the present engine, in some cases, the action of the crank upon the center will be greater than its action upon the piston, as 11 to 4; but supposing the difficulties in the execution to be conquered, still this must happen, that as the barrels in moderate space of time will sensibly chamber, and the middle part of the barrel, so far as the short stroke reaches, will be always in wear, but that part above and below the limits of the short strokes only in wear when the long stroke is used, it follows that the barrels will chamber unequally. An engine will go very well with its barrel a good deal chambered; in short, they are seldom rebored so long as a new leathered piston can be got in at the mouth so as to fill in the chambered part, but then as they chamber nearly equal, and the stroke remains the same, that of the barrel in which the piston moves is still nearly a cylinder; but, in the case of unequal strokes, the piston would be obliged to move through a space alternately narrower and wider, which would cause it to work very hard.

Again,

Again, as it might be sometimes for some days together in neap tides that the long stroke would not be made use of, the extra parts in that time would in iron barrels grow rusty, and when used again would not only cause the engine to go still harder, but also destroy the leathers. This last inconvenience would indeed be remedied by brass barrels; but where the charge and difficulty is great, and the effect not greatly superior, an invention so circumstanced is less eligible. This thought of altering an engine's power by a different length of stroke is not new to me, having had the same thought ten years ago; but while I was contriving the machinery necessary to perform it, the objection of the unequal chambering of the barrels occurred to me, which made me lay it aside, though cases have occurred to me in which it would otherwise have been applicable and useful.

It now comes in place to enquire into the general proportions and adjustments of the engine, to work at strength of tide; and I agree with the inventor, that a wheel of large diameter will wade in a great depth of water to more advantage than a moderate one; that a great breadth of float-board will resist the current more than a narrow one, and, consequently, give more power to the engine; and that the wheels, at strength of tide, may, with advantage, be made to move with a greater load than they do at present, but advantages carried to extremes often prove disadvantageous, according to the proverb, things in a middling way are frequently best.

With respect to the water wheel's height, that a wheel of 30 feet will get better through the water when wading at a given depth than one of 30 or 25 feet, is already allowed; but then as it moves proportionably slower, what is lost in number of revolutions of the first mover (in order that the same quantity of water may be raised) must be gained in the second; so that the same spur wheel will act on a less wallower, or a larger spur wheel acting upon the same wallower, produces a proportionably greater strain or twist upon the axis of the water-wheel; again, if more engines are put on, or with longer strokes, or both, the strain will be greater in proportion to the increase of water drawn thereby; if, therefore, the 25 feet wheel's axis goes $6\frac{2}{3}$ turns for the proposed wheel's 3, the strain upon the old axis to that of the new will be as 3 to $6\frac{2}{3}$, supposing the same work done by both; but if the work done is more in the proportion of 15 to 27, the number of hogheads supposed to be raised by each, or, as I calculated it, 13,2 to 26,7, the compound proportion will be 39,6 to 17,8, that is, the strain or twist upon the new wheel's axis, when at its lesser stroke, will be $4\frac{1}{2}$ times greater than that of the present 25 feet wheel; so that it is much to be questioned, whether an axis of 3 feet diameter, (which I apprehend to be that here proposed) or indeed any timber that can be got, will bear the strain so as to be sufficiently lasting.

The size, disposition, and machinery of the floats I think is very good, but I think a smaller number would do as well in this situation: as to the fall proposed to the break of the wheel, I think it not only expensive and difficult here to lay, but useless in this place on tide of ebb, and detrimental to the action of the wheel on tide of flood. The proposition of increasing the number of barrels I can by no means approve, for either another crank must be added, or there must be six barrels to each engine, either of which will be attended with inconveniencies, more complication, and more increase of friction than is necessary.

Lastly, with respect to the comparison of the effects of the old and new engine, I lock upon it as a matter of certainty, from observation, that the 25 feet wheel moves $6\frac{1}{2}$ revolutions at strength of tide, and, therefore, that its mean circumference moves through a space of 495, or, as I make it, of 497 feet, and, in this case, bona fide raises 13 hogsheds of 63 ale gallons each per minute; but what is the velocity of the water driving the wheel, by no means appears, we are sure the natural velocity of the water must be greater than the wheel, but whether it be $\frac{1}{8}$, $\frac{1}{6}$, $\frac{1}{4}$, $\frac{1}{3}$, or $\frac{1}{2}$, by no means appears; the number 619 therefore, expressing the velocity of the water per minute, cannot be considered otherwise than as conjectural, and, consequently, the number 3612 hogsheds expended per minute, deduced therefrom, must be conjectural also: the acting head to produce 619 feet velocity is 1 foot 8 inches nearly, not two feet as here supposed; but if 619 is conjectural, the head 1 foot 8 inches must be also conjectural.

The mean height to which the water was supposed to be raised, viz. 100 feet, I apprehend is also conjectural, since it rises higher or lower in the stand-pipe, as there are a greater or less number of cocks open upon the mains: now if 100 be divided by 1 foot 8 inches, the quotient is 60; but as both the divisor and dividend are conjectural, the quotient will be still more so, and this being again a divisor to the conjectural number 3612, the quotient, which will be 60, will be still more conjectural; but supposing the number 619 and 100 both right, or nearly so, then the number of hogsheds equivalent to the power will be 60, but still there remains a difficulty what proportion of this quantity we must take for the neat performance of the engine; few or no engines that I have seen have yielded $\frac{3}{4}$, most fall short of $\frac{1}{2}$, and the present engine less than $\frac{1}{2}$, but more than $\frac{1}{3}$, that is, in case we are right in the two numbers before-mentioned, because if we are not, we still remain uncertain what the effect thereof is, in proportion to the power producing it. All, therefore, that we can fairly conclude is this, that a greater quantity of float-board will give a greater power, and a greater capacity of pumps will raise a greater quantity of water, provided we do not overload our power, or break our tackles by overstraining.

GASCOIGNE.

GASCOIGNE ON RAISING WATER OUT OF SHIPS.

EXAMINATION of Mr. GASCOIGNE's proposals for raising water out of Ships. By JOHN SMEATON.

RESPECTING that part of his proposal which consists in applying the forcing pumps to the raising of water out of the hold of a ship, by which means he is enabled to place the most essential parts of his machinery below the water line, is a merit that will be obvious to every seaman; I shall therefore not take up time in saying more about it than that it seems worth attending to, in case the conveniency of a ship will admit its execution, and the more especially as I am very certain, from experience, that as much water may be raised in this way as any other. But in regard to the great preference Mr. GASCOIGNE gives his pump above the chain pumps, in point of quantity delivered, and in point of power wherewith he proposes to work it, I can by no means agree with him. He proposes to raise 86 tons of water per hour to the height of 22 feet, by four men; whereas he gives us to understand, that the common chain-pump requires 14 men to raise 60 tons per hour to the same height; a very surprising difference indeed! In order to prove this, he has recourse to calculation, and, as a ground-work, make this *supposition*, that four men will turn round the winch or handle of his machine 60 turns per minute, in which case, as this will produce a stroke of 1 foot long in four pump-barrels of 6 inches diameter each, this will necessarily produce a certain quantity of water per hour, which he calls 86 tons, but which, according to my computation, (supposing none lost) is scarcely 84; but this I pass over: now if, on the other hand, we suppose that four men *cannot* turn round the winch 60 turns per minute, then the whole computation falls to the ground. He endeavours further to support himself by a comparison of the friction of his engine with the chain-pump; in order to this, he calculates the number of frictions in his machine, and gives each of them a determinate value, viz. four pounds; he also calculates the number of frictions in the chain-pump, and calls each of *them* five pounds; but as this is a method of computation totally new to me, and as he has given no sufficient reason why he calls a friction in one machine four pounds, and in the other five, nor why he might not as well have called them four ounces each, or 40 pounds, as best served his purpose, I shall not take up any more time in pursuing him any farther in this road, but shall endeavour to set the whole in clear light.

DESAGULIERS, in the second volume of his Experimental Philosophy, has taken a good deal of pains in finding out a kind of land-marks to guide us in those kinds of pursuits, and to enable us to value the pretensions of projectors in the art of raising water; and he has told us, that the mean strength of a man, when applied to the best kind of pump that has been yet in use, amounts to no more than the raising one hoghead of water in a minute to the height of 10 feet; for my own part, I have made a variety of machines and many observations of this kind, but never yet found the value of mens strength at a medium equal to what is set down by DESAGULIERS, unless they are supposed to work in haste, or distress, for a few minutes; however, as it is more favourable to Mr. GASCOIGNE's proposal, we will for the present suppose the performance of men equal to what is stated by DESAGULIERS, viz. one hoghead per minute at 10 feet high, that is, at the rate of 60 hogheads per hour.

Now by the unalterable laws of hydrostaticks and mechanicks, if a man can only raise 60 hogheads 10 feet high per hour, he can only raise 30 hogheads to 20 feet, and only $27\frac{1}{4}$ hogheads to 22 feet in an hour, by the same rule of proportion. Now $27\frac{1}{4}$ hogheads, consisting of 54 ale gallons, as supposed by DESAGULIERS, makes $7\frac{1}{8}$ tons nearly, that can be raised by one man per hour, to the height of 22 feet, and consequently that $28\frac{1}{2}$ tons per hour is the utmost that can be raised by 4 men, instead of which Mr. GASCOIGNE proposes to raise 86.

If we examine what he has stated concerning the chain-pump, by the same rule, we shall find its pretensions more modest: he supposes the chain-pump to raise 60 tons per hour by 14 men; now if $7\frac{1}{8}$ tons per hour is all that can be raised by one man to the height of 22 feet, 14 times $7\frac{1}{8}$ tons equal to $99\frac{3}{4}$, or in round numbers 100 tons, is the utmost that can be raised by 14 men, instead of which the chain-pump only raises 60; so that here it falls considerably short of the mark. However, we may hence conclude, that as the chain-pump is deficient only 40 parts in 100, that all the pump-work that can be contrived will never exceed the present chain-pumps above the proportion of 60 to 100; whereas, men and quantity considered together, Mr. GASCOIGNE proposes to improve upon the chain-pumps in the proportion of 60 to 301, which is the number of tons that ought to be raised by 14 men, according to Mr. GASCOIGNE's method. For my own part, I believe that the friction naturally attending the chain-pump will never admit its performance to be quite equal to what can be done by other known kinds of pumps; but as it is capable of some improvement, I am clear that it might be made to raise 75 tons per hour instead of 60, and with more ease to the same hands.

It may perhaps be imagined that there is something in Mr. GASCOIGNE's machine that is new, and preferable to all those that may be made trial of; but I beg leave to observe, that it differs in no essential point from the crank machines commonly made use of for raising water by water or horses for gentlemen's seats, brewers, distillers, dyers, &c. though not that I know of applied to ships; and in point of raising water, I look upon it not quite so well adapted as the machine he describes, and calls the store-pump at *Portsmouth*, because a three-necked crank works more equably, and is attended with less friction than four: and in regard to his application of an air vessel, though useful on many occasions, is of no use on the present; it must, however, be allowed, that the form of the pump in store at *Portsmouth* is much more cumbersome, and less adapted to the convenience of a ship, besides the inconvenience of some of its essential parts being above the water line. I apprehend Mr. GASCOIGNE's machine capable of some improvements, by which it might be made to raise about 80 tons an hour with 14 men, instead of raising 86 tons with four men, and if its situation will be agreeable to the convenience of ships, may be used to a very good purpose.

London, January 20, 1765.

J. SMEATON.



BRISTOL HARBOUR and CANAL.

PROPOSALS for laying the ships at the quay of *Bristol* constantly afloat, and for enlarging this part of the harbour by a new canal through *Cannon's Marsh*, by JOHN SMEATON.

1st. **I**T is proposed to keep the water in the quay and new canal to the constant height of the 15 feet mark upon the lowermost marked staff upon the quay next the *Avon*, and clearing away 2 or 3 feet of the mud there laying, to make from 17 to 18 feet water.

N. B. The 15 feet mark is about 6 feet below the top of the quay, and about 4 feet below the spring-tide high water mark of the 24th and 25th of January, 1765, which, though not the largest, were nevertheless accounted considerable tides.

2dly. It is proposed to dig the new canal as far as the sluices, so deep as to make 18 feet water therein at the said proposed level, and to make the same at least 100 feet wide in the clear.

3dly. To drop the tail of the new canal into the river *Avon* at the bottom of *Cannon's Marsh*, just above the *Glass House*.

4thly. To construct two separate sluices, one as near as conveniently can be to the river *Avon*, upon the tail of the canal, the other at the distance of 400 feet from the former, further within the canal; both these sluices to be furnished with two pair of pointing gates, one pair in each sluice pointed to land, the other to seaward. The width of the chamber, or space intercepted between the two sluices, to be 60 feet, and the width of the sluices to be capable of taking in the largest ships that use the port, which I suppose will be done by an opening of 30 feet wide.

5thly. The threshold of the upper sluice to be laid at the depth of 18 feet below the constant water that is even with the bottom of the canal; but the floor of the chamber between the two sluices, as well as the threshold of the lower sluice, to be laid as low as the bottom of the river in the shallowest place, below the tail of the canal.

6thly. These things being executed as before mentioned, the present mouth or opening of the river *Froome* into the *Avon* to be stopped up by a solid dam of earth, furnished,

furnished, however, with such draw-hatches as may be necessary to assist the hatches in the gates of the sluices in discharging the freshes of the river *Froome* in rainy seasons, but yet so as to make a communication for all kinds of carriages from the *Back* and *Quay* down alongside of the new canal between the same and the river.

7thly. The whole of the new work to be wharfed with stone, so as to form quays or such other conveniencies as shall be found necessary.

8thly. To erect draw-hatches at the new bridge at the head of the quay, capable of retaining the water behind them when the water in the new canal and quay is let off.

9thly. To have the command of the hatches, and to erect new ones, if necessary, upon the pond of *Newgate Mill*.

N. B. By the constructions above proposed, *Tom's Dock* and *Bridwell Mill* will be rendered useless, but *Newgate Mill* will be benefited thereby.

OPERATION of the foregoing constructions.

When the tide is out, the water of the canal is proposed to be retained by the land-gates of the upper sluice, all the rest being open on tide of flood. As the vessels come up, they go into the chamber between the sluices, where they always find equal water with that they came up with, which chamber is capable of holding eight ships, or four ships and six troughs, at the same time; here they wait at spring tides till the flood in the chamber is upon a level with the canal, at which time the sea-gates of the lower sluice are put to, which prevents the tide's water flowing into the canal; the land-gates of the upper sluice are then opened, and the vessels proceed to their births.

Then the large vessels that are going down, that require to depart at high water, are brought down into the chamber while the tide is flowing; the sea-gates of the upper sluice being then put to, and the hatches of the sea-gates of the lower sluice drawn, the chamber fills to the level of the tide in the river, and the sea-gates of the lower sluice are opened; and if any deep vessels are arrived after the tide had rose to the level of the canal, they may now be taken in, where they wait all together till high water, when the outward bound depart, with the first moment of the ebb, and the inward bound wait till the tide has sunk to the level of the canal; at which time the land-gates of the lower sluice are put to, and the sea-gates of the upper sluice are opened, which gives those ships leave to go to their births, and at the same time to take

in such of the vessels as are outward bound, and can go down with the remainder of the ebb, after the water is fallen to the level of the canal ; which vessels being brought into the chamber, the land-gates of the upper sluice are put to, and the hatches of the land-gates of the lower sluice drawn, by which means the water in the chamber is reduced to the level of the tide in the river ; the land-gates of the lower sluice are then opened, and the vessels depart, leaving the sluice in the same position as we found it.

Hence it appears, that two sets of vessels may go up and two down in one tide, when the spring tides rise above the level of the canal's water, and that without the admission of any tide-water into the canal, except what happens to get in by the disturbance of the water by the passing of vessels, which, as it will lodge near the upper sluice, the greatest part will be drawn through the hatch of the land-gates of the upper sluice ; which ought to be drawn at low water, to let off the water accumulated in the canal and quays by the currency of the river *Froome*, and to scour the chamber and the lower sluice from the mud left by the tide.

At neap tides the vessels inward bound come into the chamber as before, as soon as they have water, and wait all together till high water, which being below the level of the canal, the land-gates of the lower sluice are then put to, and the hatches of the land-gates of the upper sluice drawn ; by which means the chamber will fill to the level of the canal, and as the land-gates of the upper sluice may then be opened, the vessels may proceed to their births, and those that are ready to go down may hawl in ; after which the land-gates of the upper sluice being put to, and the hatches of the land-gates of the lower sluice drawn, the water in the chamber is then reduced to the level of the tide in the river ; the gates of the lower sluice may then be opened, and the vessels proceed with the tide.

When water is plentiful in the river *Froome*, the vessels going up at neap-tides may be penned through the chamber, by drawing the hatches of the upper land-gates some time before high water, which will afford more time for the vessels going down to get into the chamber before the tide is much abated ; otherwise it will be most advisable, that after the vessels going up are gone out to their births, to keep the water against the land-gates of the lower sluice till the next tide, when all the vessels going out will have time to get into the chamber, and be ready to go out all together at high water. By this method of passing, the vessels inward bound one tide and outward bound the next, they will all have all the benefit of the full tide, and the whole of the water expended in twenty-four hours will be only so much from the canal as is necessary to fill the chamber from the level of high water to the level of the canal ; and I apprehend the
season

season is seldom so dry, but that the currency of the *Froome* will, at an average, replace this to the body of water contained in the new canal and quays in twenty-four hours; but, by way of further supply, as no water will be wanted from the canal to pass the vessels in spring tides, an accumulation of 1 foot may be retained without prejudice, which, upon so large a surface as will be contained in the new canal and quays, would alone be nearly equivalent to the water expended in the chamber for passing the vessels, according to the last proposed method. Yet, as a sheet anchor, the pond of *Newgate Mill* may be had recourse to, upon paying an equivalent; but which, from the reason already stated, I don't apprehend can be wanted above once in seven years.

As by this method the tide-water will be almost wholly excluded, there will not be a need of often scowering; but, when this is done, the hatches proposed at *New Bridge* will be of use, and the hatches upon *Newgate Mill Pond* will be still of further use; but I don't apprehend this operation will be needed above twice, or at most four times a year.

OBSERVATIONS.

1st. A power of diverting other streams into the river *Froome* upon necessary occasions may be of use, and of making reservoirs for water.

2dly. The sea-gates of the upper sluice are to have no draw-hatches, which will effectually prevent the ships from penning into the canal with the tide's water.

3dly. By these constructions, whenever there is water to bring up a ship to the tail of the canal, she is always enabled to get to the quay.

4thly. The ships being kept constantly afloat, the river *Froome* will of itself birth a great number, and the new canal will birth twenty-four ships, besides leaving a sufficient passage; but, by making it wider, will birth a greater number; every ship's breadth in width makes an addition of twelve births.

5thly. The expence, as near as I am at present enabled to calculate the same, will be as follows.

	£.	s.	d.
To digging, - - - - -	6555	0	0
Quay walling, - - - - -	4887	0	0
The two sluices, - - - - -	8000	0	0
The dam and hatches across the present mouth of <i>Froome</i> river, -	1000	0	0
The hatches at <i>New Bridge</i> and upon <i>Newgate Mill Pond</i> , -	600	0	0
Contingent expences being supposed, - - - - -	3958	0	0
	£.	25000	0 0

Exclusive of purchase of lands and damages to *Bridewell Mill* and *Tom's Dock*.

Bristol, January 26, 1765.

Bristol, January 26, 1765.

AT a numerous meeting of the merchants of the city of *Bristol*, this day held, JOHN SMEATON, Esq; having presented to them a scheme and plan for laying the ships at the quay of *Bristol* constantly afloat, and for enlarging that part of the harbour by a new canal through *Cannon's Marsh*, it was unanimously voted, that the thanks of the gentlemen present be given to Mr. SMEATON for his plan now offered, and for his diligence and attention in this matter.

THO. SYMONS, Clerk.

Austhorpe, December 31, 1766.

HAVING perused and considered the plans this day laid before me relative to *Bristol Harbour*, * I am of opinion, that the uppermost and lowermost where the sluices are made out of the river, and the dam upon the channel of the river, are more practicable and eligible than the middle scheme, where the whole is done within the bed of the river, and provided the expence of the execution of either of those schemes is no objection, there is no other material one that occurs to me; and respecting the eligibility of the upper or lower scheme, as there is no difference but what relates to convenience and expence, this is a proper subject for the determination of the merchants of *Bristol*. But whichever of these schemes are executed, I advise, if two passages are made, to keep them entirely separated by a middle wall, and to raise these walls and gates at least 5 feet higher than the crown of the dam, especially at that end next *Bristol*.

J. SMEATON.

* Designs of Mr. CHAMPION, who came with them into *Yorkshire* in company with Mr. SYMONS, Clerk of the Company.

PORTABLE FIRE-ENGINE.

DESCRIPTION of a Portable Fire-Engine, invented by JOHN SMEATON, F. R. S. at the instance of the Right Honourable the Earl of EGMONT, 1765.

No. 1. **S**HEWS the ground plan of the walls for supporting the engine, which is supposed to be necessary, in order to keep the several parts of the machinery from settling under the weight, wherein,

- A. B.* is the pit or shaft.
- C. C.* foundation walls on each side of the pit, for supporting the fore part of the engine frame across the pit.
- D. D.* a foundation wall in like manner, for supporting the back part of the frame.
- E. E.* walling under the boiler.
- F.* shews the center of the boiler.
- G.* the place of the cylinder.
- H.* the main pump.
- I.* the jack-head pump.
- K. K.* the ash hole.

No. 2. contains elevations of the engine, viz. an end and side view thereof, when put together, wherein the same letters as are in the plan refer to each.

- A. B.* is the pit or shaft.
- C. C.* the upright of the foundation walls on each side of the pit, for supporting the groundfill *c.* across the pit, upon which one side of the engine frame is raised.
- D. D.* the foundation wall, for supporting the groundfill *d.* upon which the other side is raised.
- E.* foundation wall for supporting the boiler, and forming the ash-hole.
- F.* is the boiler, *f.* the fire-door, *g.* the chimney, *s.* the steam-pipe, *p.* the puppet-clack, *v.* the feeding-pipe funnel, *z.* the man-hole.
- G.* the cylinder.
- H.* the main pump-spear.
- I.* the jack-head pump, by the continuation whereof *k. k. k.* the water is conveyed into
- L.* the injection cistern.

M.

M. a wheel serving instead of the great beam, *m.* a rim of a smaller diameter, attached to the former, for working the jack-head pump *I.* and plug-frame *Q.*
a. a. pulleys to bring their chains into a convenient place for working. The wheel is stopped at the end of it's intended stroke, which is to be $6\frac{1}{2}$ feet, stop and stop, by means of the two iron fidds *b. b.* which, reaching out on each side of the great rim, stop against two strong iron pins *c. c.* which are fixed into a cross beam *S.* framed into the piece *T.* and the whole firmly bolted together, as shewn in the design; *N.* is the injection-pipe, *n* the injection-cock, and *x.* the piston water-cock.

O. is the hot well.

R. a stage for the person to stand upon, who hands the engine.

P. P. are the two main-beams or sleepers, upon which the cylinder is seated upon it's bottom, and bolted down; the whole is kept from springing or flying off by the iron strap *q.*

N. B. The waste water-pipes are omitted to prevent confusion.

No. 3. Fig. 1. shews a section of the boiler, cylinder, and pipes, with the working-gear, to a larger scale, the whole being divested of the framing, in order to render every thing more distinct.

N. B. The boiler is supposed to be turned one quarter round, from it's true position, as in No. 2. in order that the most material parts may be brought into one view. It is also to be noted, that every vessel or pipe is supposed to be cut right through the middle, in order to shew the contents, and not that the section is confined to any particular plane; but, for the more perfect explaining of the principal figure, it will be best to begin with the little plan marked Fig. 2. wherein

A. B. C. D. is a plan of the cylinder bottom, bolted down upon the two main beams *A. B.* and *C. D.*; the dotted circle *E. F.* shews the extremity of the bottom flanch of the cylinder, and the circle *G. H.* the diameter of the cylinder within; the hole *I.* answers the steam-pipe and regulator; and the hole *K.* the eduction or sinking pipe, and the circle *L. M.* it's flanch; the circle *N. O.* shews the size and position of the regulator plate, and the dotted circle *P. Q.* the size of the receiver, in which the sliding valve of the regulator *R.* works, and in this position is open; *S. T.* is the lever by which it is worked; and when that is brought forwards into the position *S. V.* then the valve covers the aperture of the regulator.

Explanation

Explanation of Fig. 1.

A is the boiler, and

B the fire-place, which is intended to be of a spherical figure, of cast iron, and intirely within the boiler; the coals are to be introduced by the large pipe or opening *C* and the smoke carried off by the curved pipe *D*; and, in order to promote a sufficient draft, the iron funnel *E*. is added. The ashes fall through the grate *S* and wide pipe *F*, into the ash-holes below. The whole being joined to the boiler by proper flanches, as is shewn in the figure, and always covered with water, as will be known by the two gage cocks *a*, *b*.

Though it is expected that a small force of fire thus applied will keep the engine going, yet as that force cannot be wholly exhausted within the compass of the boiler, it is proposed to surround the curved pipe *D* with a copper vessel, somewhat adapted to the shape thereof, as represented in the figure, in which it is proposed to bring the feeding water, which will hereby be prepared to a greater degree of heat than if brought immediately from the hot well into the boiler; into which it is to be introduced by the little hole at *c*.

The bars of the grate *S* are intended to be cast in a loose ring, capable of being taken out, and replaced when occasion requires.

T a cock for emptying the boiler when it wants to be cleaned.

G is the cylinder into which the steam ascends from the boiler, by the pipes *d e H I*, of which *d e* are the copper, and are disjunct at *f*, for the sake of taking the engine easily to pieces; and are joined by first bending a piece of lead round the joint, and then wrapping them with cloths and cords, as is common in great engines.

H is the receiver for the steam, of cast iron, containing the regulator valve; and *I* is the steam pipe, by which the steam passes to the cylinder when the regulator valve is open, which in the present situation of the engine it is supposed to be, in which case the piston *K* will begin to return.

L is the snifting clack, at which the steam at this instant blows out.

M the injection cock, which is now shut.

N the injection pipe, which brings down the water from the cistern above.

O that part of the injection pipe that conveys the water into the cylinder, when the injection cock is opened, and which terminates in a cap that directs the jet of water perpendicular; the injection cap is in the center of the cylinder, but as part of the termination of the injection pipe lays behind the steam pipe *I*, it hinders the complete view thereof; the other parts will perhaps be better described by an explanation of the operation of the engine.

Operation of the engine.

To render this explanation intelligible, it is to be premised, that the plug-frame *P*, which moves up and down with the piston, but with a different velocity, according to the diameters of the two wheels, (*M* and *m* No. 2) is furnished with pins, which lay in four different planes, answerable to four different detents or arms of the working gear: the pin 3 lays upon the fore side; the pin *g* lays in a mortoise, which divides the plug-frame into two parts, the pins *S*, 1, 2, lay upon the far side, and the peg *p* stands in the place of the plug-frame, upon the further check. Now when the piston is risen as high in the cylinder as it's stroke is intended, the pin *g* having met the arm *b* of the tumbler *i k*, oversets it into the position *i m*; so that the point *k* moving into the place of *m*, the regulator valve is shut, by drawing the rod *k o*, which takes hold of it's lever towards the plug-frame; and at the same instant the peg *p* rising so as to lift up the catch *q*, the beak of the faller (or *F* as it is commonly called) marked *r*, is disengaged therefrom, and the weight *w*, by descending into the place *v*, carries the fork *x* along with it, and therewith the lever that turns the injection cock into the place *y*, and whereby that cock is opened, the jet played, and the steam reduced into water, (or condensed, as it is commonly called) hereby a vacuum being produced within the cylinder, the pressure of the air causes the piston to descend, and in descending, the peg *S*, on the far side, meeting the faller at *t*, carries it down to *z*, which shuts the injection cock, and also hooks the beak behind the catch *q*, and thereby the tail *t* becoming parallel to the plug-frame, the pins succeeding the pin *S*, retain it in the same position, the piston still descending till the peg 3 on the fore side laying hold of the arm 4 of the tumbler at *n*, thereby brings back the regulator into it's present position, and the further descent of the piston is stopped by letting in the steam.

The water thrown in by the injection at each stroke, and also generated from the steam, is evacuated while the piston is rising, by means of the eduction or sinking-pipe, and valve *Q*; this pipe laying exactly behind the steam-pipe *I*, is thereby, in a great measure, hid; the steam-pipe is carried several inches above the bottom of the cylinder, to prevent the injection water from running into the boiler; but the eduction-pipe rises no higher than the bottom, in order to lead the water into it; and as the bottom of the cylinder is commonly elevated from $1\frac{1}{2}$ to 3 feet above the valve at the bottom of the eduction-pipe, commonly called the horse-foot valve, the pressure of this column of water opens the valve, and makes it's way into the cistern *R*, called the hot well; but when the vacuum is made, this valve shuts, and being immersed under the surface of the hot well water, is thereby kept air-tight.

As there is a considerable quantity of air lodged in water, when in it's natural state, which separates itself by boiling, and, in some degree, by considerably heating, it follows that a quantity of air passes along with the steam into the cylinder, and that a further quantity escapes from the injection water, by being considerably heated with the steam; and though air is capable of being considerably expanded by heat, and contracted by cold, yet the degree is so very much less than that of steam, that if the air generated at each stroke was not evacuated, it would quickly render the vacuum so imperfect, that the piston would stop in the middle of it's descent. Now as the air will be lodged, when the piston is down, between the surface of the injection water laying upon the bottom of the cylinder and the piston, in order to get rid of it, the snifting clack *L* has been happily applied; for, on the first rush of the steam into the cylinder, the piston not being instantly put into a contrary motion, the steam, finding a passage at the snifting clack for a small space of time, blows out thereat, and therewith carries the whole or the greatest part of the air generated at each stroke, so as to prevent it's increase beyond a certain degree.

The surface of the hot well water being in general from 3 to 5 feet higher than the surface of the water in the boiler, this height of column is sufficient to force it's way into the boiler, though resisted by the action of the steam within, when sufficiently elastic for use; it therefore finds it's way down the feeding-pipe 5, 6, through the feeding-cock 7, which is opened so much as is found necessary for supplying water to the boiler as fast as it is consumed in steam. It is evident, that whenever the repellancy of the steam within the boiler is not too great to suffer the surface of the water in the feeding-pipe to be below that of the hot well, that the boiler will feed by the passage of the water into the pipe; but whenever the repellancy of the steam is such as to keep the water in the feeding pipe above that point, that then the water will revert into the hot well; but as the repellancy of the steam within the boiler is alternately greater and less, as the regulator valve is shut or open, during each stroke of the engine, it follows that the boiler may feed while the cylinder is drawing the steam from the boiler, and revert while the piston is descending. In order, therefore, to make this matter safe, and at the same time to bring the engine into as small a compass as possible, the valve 8 is placed in a little box in the hot well, to prevent such a reversion. It is necessary to continue the feeding-pipe as usual considerably above the hot well; for as the water is in a vibrating state within this pipe, according to the variable repellancy of the steam within the boiler, this extension is to prevent it's frequently overflowing; for it is necessary to be open at the top, otherwise the steam generated therein would prevent it's feeding at all, or very irregularly.

N. B. The hot well is, in this view of the machinery, represented considerably larger than it is; for supposing the boiler turned a quarter round while the feeding-pipe 5 6 falls directly behind the puppet-clack 9, as shewn in the general elevation, the hot well will then be shorter by half the diameter of the boiler.

The puppet-clack 9 has no other use than being loaded with a certain weight, in proportion to it's size, that whenever the repellancy of the steam in the boiler is greater than to lift up this clack, it evacuates without bursting the boiler, which it otherwise might do, and, when the engine is stopped, the person attending lifts it up by the cord 12, 13, in order to discharge the steam.

A pipe of communication for steam, 10, 11, between the receptacle for feeding and the boiler, will be necessary; for while the boiler is heating to make the engine work, (after standing some time) the feeding-cock being then shut, the water in this receptacle will boil before that in the boiler, and possibly, by the sudden expansion of the steam upon boiling, might burst this vessel before the water could be evacuated at the little hole c, and yet, if so, being emptied of the water, might, by overheating the copper, break the soldered joints.

N. B. It is to be understood that in this, as in all other engines, the weight of the main pump-spear is so far to exceed the weight of the piston as to raise it, and overhaul all the gear, and that if not so, must be weighted till it will do it.

I have said nothing of the measures, for as every thing is drawn to the scale annexed, I did not chuse to perplex the account therewith.

Calculation of the effects of this engine.

The diameter of the cylinder being 18 inches, the area in circular inches will be 324 inches, and allowing 7 lb. to the inch, which such a cylinder will very well carry, we shall have 2268 lbs. equal to the weight of the column of water to be lifted = 1 ton and 1 quarter of an hundred weight.

The pump working barrel being supposed of 7 inches diameter, the weight of a column of water that size, and 1 foot high, is 16.7 lbs. by which dividing 2268 lbs. to be raised, we have 135.9 feet for the height of the column = 22 $\frac{1}{2}$ fathoms nearly, by a similar process, if the working barrel is 8 inches, the height of the column raised, will be 17 $\frac{1}{2}$ fathoms, and if of 9 inches, 13 $\frac{1}{2}$ fathoms.

Such

Such an engine may be expected to make ten strokes per minute, of 6 feet each, effectively; this, with the 7 inch bore, will produce $98\frac{1}{4}$ ale gallons per minute, that is 113 hogsheads wine measure per hour; the 8 inch bore will produce $128\frac{1}{4}$ ale gallons per minute, that is, 148 hogsheads per hour; and the 9 inch bore will produce $162\frac{1}{2}$ gallons per minute, or 187 hogsheads per hour.

It has been found by experience, that a 2 feet cylinder can be worked by one bushel of Newcastle coals per hour; the present cylinder being but 18 inches, the capacities will be as 16 to 9; therefore if a 2 feet cylinder takes 24 bushels per day, an 18 inch cylinder will take but $13\frac{1}{2}$ bushels per day, according to the common application of fire; but I have reason to think an engine constructed like this will not require above 9.

It has also been found by experience, that a horse will raise about 250 hogsheads 10 feet high per hour; consequently only $30\frac{1}{4}$ hogsheads at $13\frac{2}{3}$ fathom = 82 feet; but 187 hogsheads raised to that height by the engine, is more than six times the quantity raised by one horse, and consequently acts with more than the power of six horses at a time; but in order to keep up this force with horses, night and day, three sets will be required, and consequently this engine will be more than equivalent to eighteen horses.

WHITBY HARBOUR.

Yorkshire, to wit, At the assizes held at the castle of *York*, in and for the said county, on Saturday the 20th day of July, in the fifth year of the reign of our Sovereign Lord George the Third, by the grace of God, now King of *Great Britain*, &c. and in the year of our Lord 1765, before the Honourable Sir HENRY GOULD, Knight, one of the Justices of his Majesty's Court of Common Pleas, and the Honourable Sir JOSEPH YATES, one of the Justices of our Lord the King, assigned to take the said assizes according to the statute.

CHOLMLEY, Esq; against HOWLETT and MATHEWS.

IT is ordered by the consent of the said parties, and their attornies, that the last juror or jury empannelled and sworn in this cause be withdrawn from the said pannel, and by the like consent it is ordered that the plaintiff shall execute, and the defendants shall accept, a lease with proper covenants for repairs by the defendant, and all other usual covenants, of the plaintiff's mills and fishery, in the pleading of this cause, mentioned at a rent equal to the highest neat profits, to be computed on a mean of any three successive years to be named by the plaintiff, which shall appear to the satisfaction of FOUNTAIN WENTWORTH OSBALDESTON, of *Hunmanby*, SIMON BUTTERICK, of *Thirsk*, and JOHN GRIMSTON, of *Kilnwick*, Esqrs. or any two of them, to have been made at the premises by the plaintiff; and also to enter into such covenants for cleansing the harbour of *Whitby* from the allum shail, which hath come from the defendant's works, within such time and in such manner as JOHN SMEATON, Esq; and JOHN WOOLER shall think reasonable, and also for the security of the said harbour from future damage from the defendant's allum works. The survey and award of the said JOHN SMEATON, Esq; and JOHN WOOLER to be made on or before the 7th day of November next, and at the joint expence of the said parties; and it is further ordered that such security shall be given, and penalties provided for the performance of the aforesaid covenants, as the said FOUNTAIN WENTWORTH OSBALDESTON, SIMON BUTTERICK, and JOHN GRIMSTON, or two of them, shall think reasonable and sufficient, and that the lease to be made shall be executed on or before the 20th day of December next, and shall commence, together with the rent, at that time, for the term of 99 years.

And it is also ordered that there shall be no costs on either side, and that the defendants shall consent that the plaintiff's bill, now depending in the Court of Chancery, shall be dismissed

missed without costs ; and that all other proceedings or actions now depending between the said parties, either at law or in equity, touching the matter in question in this cause, shall cease, and that no writ of error shall be brought, and that no bill in equity shall be filed against the said FOUNTAIN WENTWORTH OSBALDESTON, SIMON BUTTERICK, JOHN GRIMSTON, JOHN SMEATON, and JOHN WOOLER, or any of them, for any thing done by them under or by virtue of this order ; and that this order shall be made an order of his Majesty's High Court of Chancery, if the Lord High Chancellor shall so please.

By the Court.

To all to whom these presents shall come, JOHN SMEATON, of *Austhorpe*, in the county of *York*, Esq; and JOHN WOOLER, of *Whitby*, in the said county, Gent. send greeting. Whereas, by rule of court, made at the assizes held at the castle of *York* in and for the county of *York* on Saturday the 20th day of July, in the 5th year of the reign of our Sovereign Lord George the Third, by the grace of God, now King of *Great Britain*, and so forth, and in the year of our Lord 1765, before the Honourable Sir HENRY GOULD, Knight, one of the Justices of His Majesty's Court of Common Pleas, and the Honourable Sir JOSEPH YATES, Knight, one of the Justices of our Lord the King, assigned to hold pleas before the King himself, Justices of our said Lord the King, assigned to take the said assizes according to the statute, &c. in a cause then and there depending between NATHANIEL CHOLMLEY, Esq; plaintiff, and SAMUEL HOWLETT and JOHN MATHEWS, Gents. defendants, it was ordered, by the consent of the said parties and their attornies, that the last juror of the jury impannelled in the said cause should be withdrawn from the said pannel, and by the like consent it was ordered (among other things) that the said defendants should enter into such covenants for cleansing the harbour of *Whitby* from the allum shail, which had come from the defendants works, within such time and in such manner as we the said JOHN SMEATON and JOHN WOOLER should think reasonable, and also for the security of the said harbour from future damage from the defendants allum works. The survey and award of us the said JOHN SMEATON and JOHN WOOLER to be made on or before the 7th of November then next, as by the said rule of court, reference thereunto being had, may amongst other things fully appear. Now know ye, that we the said JOHN SMEATON and JOHN WOOLER having viewed, surveyed, and examined the said harbour of *Whitby* and the river *Eske* as far upwards as *Ibrondale Beck*, and the said *Beck* as far as the allum works of the said defendants, which are situate and lying contiguous to or near the said *Beck*, and also the said allum works, we find that not only the harbour of *Whitby* above the bridge there, but the channel of the river *Eske* as far upwards as the said *Ibrondale*

dale Beck, is greatly obstructed with allum shail, and also that the channel of the said *Ibrondale Beck* is greatly obstructed, and in some places nearly filled up, by the allum shail therein; and that the allum shail being in the said harbour, river, and beck as aforesaid, has all proceeded from the said allum works of the defendants, and has been carried down into the said river and harbour, in the time of floods and freshes, from the said beck; and that the said harbour of *Whitby* above the bridge there is greatly damaged thereby; and we also find that the manner in which the said allum work is carried on is such as will occasion still greater damage to the said harbour than it has yet received, by reason of other great heaps of shail and rubbish, from time to time proceeding from the said works, must necessarily fall into the said beck, and by the waters passing through the same in time of floods and freshes be washed and carried down into the said river, and from thence, by the said waters, and the additional waters coming down the said river above the said beck, carried into the said harbour, and there scattered about in an irregular manner, to the great detriment thereof, and particularly by filling up and choaking the channel of the said river, where ships of great burthen lay or have usually laid between the bridge of *Whitby* and about 160 yards above a place called the *Oil House*, and which was formerly called the *Stone Key*.

We do therefore order, adjudge, determine, and award, that the said defendants and their or one of their heirs, executors, administrators, or assigns, or some of them, shall effectually cleanse the present channel of the said river *Eske*, running through that part of the said harbour of *Whitby* laying above the bridge therefrom, and remove and carry away all the allum shail that shall be found at the time or times of such cleansing laying in the said river or harbour, between the said bridge of *Whitby* to 160 yards above the south east corner of the building or warehouse now commonly called the *Oil House*, and which was formerly called the *Stone Key*, and which shall be found above the surface of a plane regularly inclined so as to be 14 feet below the top of the uppermost aisle course of stone in the present south east angle of the said *Oil House* as it now is, and 16 feet below the top of the uppermost aisle course of stone under the threshold of the door on the east side of the warehouse or storehouse belonging to Mr. PLUMMER, being situate contiguous or near to the west end of the said bridge; and also that they shall take and carry away all such allum shail as at the time or times aforesaid shall be found laying on the sloping sides of the said channel.

And we do further order, determine, and award, that the said defendants and their or one of their heirs, executors, administrators, or assigns, or some of them, shall effectually make, do, and perform, or cause to be effectually made, done, and performed, all such cleansing of the said river and harbour as herein before ordered and awarded, on or before the 29th of September, which shall be in the year of our Lord 1766.

And

And we do further order, determine, and award, that the said defendants and their or one of their heirs, executors, administrators, or assigns, shall from to time, after the said 29th of September, 1766, take away and remove, or cause to be taken away and removed, all such allum shail as shall be found above the level of the plane above specified, or laying upon the sloping sides of the said channel; which allum shail we adjudge must happen to be so found or laying so long as the said allum works of the said defendants shall be carried on in the manner they are at present, and so long afterwards as any of the shail proceeding therefrom, and laying in the said beck and river above the harbour of *Whitby*, shall remain therein in a state capable of being removed by floods. And we do also further order, determine, and award, that all such allum shail as shall, on cleansing the said harbour aforesaid, be taken away, shall be by, or by the order, and at the cost and charges of the said defendants, their or some of their heirs, executors, administrators, or assigns, carried or removed and lodged above the high water mark of spring tides, and deposited and laid in such a manner as no part thereof may at any future period of time slide or fall down into the said harbour, or otherwise that it shall be carried directly to sea, and discharged there in not less than 14 fathom of water. And lastly, we do order, adjudge, determine, and award, that the said defendants shall, within 40 days after the date of this our award, enter into and make, and duly execute, a deed of covenants between them and the said NATHANIEL CHOLMLEY, or his heirs, wherein and whereby the defendants shall, for themselves and each of them, and their and each of their heirs, executors, administrators, and assigns, and every of them, jointly and severally covenant, promise, and agree to and with the said NATHANIEL CHOLMLEY, and his heirs and assigns, that they the said defendants, or their or one of their heirs, executors, administrators, or assigns, or some of them, shall and will from time to time, and at all times hereafter, at their own cost and charges, well and truly make, do, perform, and execute, or cause to be well and truly made, done, performed, and executed, all and every the act and acts, thing and things whatsoever, before by us ordered, directed, determined, and awarded to be by them, or any of them, made, done, executed, and performed, or cause to be made, done, executed, and performed as fully and effectually, and at or within such time or times, and in such manner as herein before mentioned, and according to the true intent and meaning of this our award. In witness whereof we have hereunto set our hands and seals this 18th day of October, in the year of our Lord 1765.

Signed, sealed, published, and declared
by the above-named JOHN SMEATON, as
his final award and determination, in the
presence of us.

VOL. I;

Signed, sealed, published, and declared
by the above-named JOHN WOOLER, as
his final award and determination, in the
presence of us.

H h

MARKET

MARKET WEIGHTON.

HAVING viewed the out-fall cloughs of *Furfdyke* and *Hudlett*, as well as the leading drains up to *Hotbam Carrs*, and from thence the country between this and *Market Weighton*, it appears to me as follows:

1st. That the most flooded part of those levels is *Hotbam Carrs*, and parts adjacent to *Wholsea*.

2d. That the general surface of the lands in those *Carrs* lay at least 7 or 8 feet above the floor of *Hudlett Clough*; and therefore,

3d. That by sufficient drains the surface of the water might be reduced 5 or 6 feet in *Hotbam Carrs*, opposite *Wholsea*, even as *Furfdale* and *Hudlett Cloughs* now stand; and therefore

4th. That all the drainages which come to *Hotbam Carrs*, by way of *Foulney* or *Black Dyke*, &c. may be equally reduced and improved; and consequently,

5th. That all the adjacent country may by proper branch drains be refitted in like manner, by running their waters proportionably lower than they can by the present drains.

6th. It appears that *Hudlett Clough* (which I look upon to be lower than that and *Furfdyke*) lays at least 3 feet above low water mark spring tides; and therefore,

7th. That by erecting a new clough of proper dimensions, the waters might be run off at least 3 feet lower than they can possibly be done by the present cloughs, though the drains leading thereto were perfect.

8th. That from *Hotbam Carrs* the low grounds have a considerable rise towards *Market Weighton*; and consequently, that

9th. The affair, so far as regards to the drainage of these levels, will be perfectly easy and well conditioned, and executed at a very moderate expence, in proportion to the extent and value of the lands to be benefited thereby.

10th. Respecting navigation, it is no ways incompatible with drainage; for provided the cuts are made at an average from 18 inches to 2 feet deeper, the drainage will remain equally good, as if no navigation.

11th. A navigation may be made any where by means of locks, where there is water to supply them.

12th. Several locks will be required between the *Humber* and *Market Weighton*, besides the sea-lock; I apprehend at least 4.

13th. I am of opinion, that the brooks formed from the springs of *Saneton* and *Houghton*, which form *Beal's Beck*, the springs at *Godmanham*, which form *Weighton's Beck*, and those of *Londebrough*, forming *Skipton Beck*, when united, as they may easily be near *Weighton*, are amply sufficient for supplying the navigation-locks thither in the driest season, and I am inclined to think the two former becks will be sufficient, exclusive of the latter; but of this I cannot be certain, unless I saw the currents of those becks in the driest seasons.

14th. I apprehend it will be equally evident from the same principles that a navigation is practicable through the levels towards *Pocklington*, as I am informed the supply of water that way is at least equal if not better; but as I suppose *Pocklington* lays in an higher situation than *Weighton*, a greater number of locks will be needful on that account.

15th. It is not possible to ascertain any thing respecting the cost of drainage or navigation towards either the towns of *Weighton* or *Pocklington*, without an actual survey of the principal drains, with a sketch of the adjacent country, as also an accurate level taken from the low water mark at the *Humber*, distinguishing the heights of the relative surfaces of the water and lands up to the respective points where the navigation or drainage is supposed to terminate.

November 29, 1765.

J. SMEATON.

A NEW BUCKET.

Description of a new Bucket for Fire Engines.

N. B. The same things are marked with the same letters, both in the plans and section.

Fig. 1st. A A is a ring of brass about $\frac{3}{4}$ of an inch thick, to be turned upon the edge so as to fit the working barrel as near as possible, but not to stick in any part; but it will not be a fault if not more than $\frac{1}{16}$ of an inch less than the barrel: this being prepared, all the rest is made from it.

Fig. 2d. B B is a ring of forged iron, about 1 inch thick, and turned or filed round upon the edge, so as to be about $\frac{1}{4}$ of an inch less in diameter than the brass ring; this ring must be pierced with 4 oblong holes or mortices C C C C, of 1 inch long and $\frac{1}{4}$ inch wide, and 8 round holes a a, &c. which are to be tapped so as to take an $\frac{1}{2}$ inch screw. This ring is also furnished with a bridge or bar D D, which may either be made of one piece with the ring, as represented at the end d, or let in with a dovetail, and rivetted, as represented at the end e, either way, as the smith can best do it, so as to make all level on the upper side. The bridge is also furnished with 3 round holes of the same size, and tapped as the former.

Fig. 3d and 4th. By means of the 4 square holes, the iron ring is to be fastened to the end of the spear rod, whose bottom part is to be divided into 4 branches, two of which, E E, are shewn in the upright section, fig. 4, and the horizontal sections thereof, fig. 3, supposed to be cut off a little above the ring, are marked with the same letters; the dotted lines distinguish the mortices, as in fig. 2d, and what lays without shews the shoulders, against which the upper side of the ring is brought square, and rivetted on the under side, by means of the tap holes in the iron ring, and the plain holes in the brass ring, which are to be made answerable to each other; the 2 rings are to be screwed together by 8 screws, such as represented f f, &c. and betwixt the rings is to be screwed the leather g g g, &c. turned up round the iron ring like a dish, the skin or hair side being next the iron ring, and the opposite or flesh side next the barrel, the middle part of the leather being cut out answerable to the inside of the rings.

H H are the valves which are to be screwed down upon the bridge by 3 screws i i i, which confine down the rider K K, which is to be somewhat sloped and rounded toward

ward the under side, to give more room for the leather of the valves to bend in the joints. I I are the upper plates upon the valves, and ~~the~~ the under, which ought to be thin, to prevent stopping the water.

N. B. Small screw bolts with thin flat heads laying underneath, will be preferable to rivets for the valves, as the leather may be more easily shifted.

L, the shank, where the 4 arms are joined into one, by which it must be united to the take-off joint.

OBSERVATIONS to be regarded in making the above.

1st. The brass ring had best be cast without holes, that when the holes in the iron ring are tapped, the brass may be marked off from it, drilled, and opened answerable to the iron.

2d. The iron ring had better not be edged till the two rings are screwed together, by which means the border may be reduced to a breadth all round.

3d. The square mortices must be chamfered or opened on the under side, in order to receive a firm rivet when filed flat, and particularly end-ways; for this purpose the mortice should be at least $\frac{3}{4}$ longer and $\frac{3}{8}$ wider below than above, and the slope to reach $\frac{1}{4}$ upwards at the ends, and about $\frac{1}{8}$ at the sides.

4th. Particular care should be taken, that the tenons of those mortices at the end of the branches should be sound and tough iron, but not the softest, and that they may be rivetted with a hammer as heavy as a common hand hammer, that the metal may spread as well within as without.

5th. The tenons of the branches, I believe, had best be formed angle-wise upon 4 square bars, for then they will be in right position, when laid flat together, in order to be welded into one.

6th. The leather dish is to be formed as follows. Prepare an iron hoop about $1\frac{1}{2}$ inch broad, as near as possible the size within of the barrel, but better lesser than bigger; prepare also a round plug of wood the size of the iron ring, Fig. 2d. but rather bigger than less; let the plug be turned truly round, of some close wood, and square at the end; let your leather be of the best bend, but not the thickest; those are best that are evenest of a thickness; cut out a circle of leather $2\frac{1}{2}$ inches more in diameter than the pump barrel, therefore for a nine-inch barrel $11\frac{1}{2}$ inches. When the leather is well soaked

soaked in water, lay it upon the ring, with the hair side uppermost, set the plug upon it, and with a few blows of a beetle, the leather will be forced into the ring, and will turn up round the sides in the same manner it is to lay in the pump, and thereby form a border without a joint of about $1\frac{1}{4}$ inch broad. When it has stood a while take it out, and put it upon the iron ring of the bucket, and with a round-faced hammer beat the leather a little down upon the ring opposite to the holes, by which means their places will be marked; cut them out with any proper sharp tool, but the best is a leather punch, which is made for the coachmakers, big enough for this purpose. This done, screw it into its place, trim it to an equal breadth, and chamfer the edge towards the barrel, as represented in the section, and cut out the middle answerable to the rings. In this way several leathers may be prepared at once, provided those that are to be kept are put on round boards, or something to keep them from drying into a lesser diameter. As the wet dries out, keep supplying them with oil, either train oil or sweet oil, or any oil that is not of a drying nature, till the pores of the outward rim of the leather that works against the barrel be in a good measure saturated therewith, and let this be done for the first leather as well as the rest; when the bucket is lowered down into its place, it would be well to pour down about $\frac{1}{3}$ of a pint of oil round the sides of the barrel, by which means, when the engine makes a stroke, the inside of the barrel will become besmeared therewith; but oil in the bending joints of the valves is rather to be avoided.

N. B. If on cutting out the circle of leather from the hide it appears thicker on one side than the other, let it be shaved with a sharp knife, so as to be of an even thickness.

If a barrel is very smooth bored without ring-galls, I esteem the surface best that is left by the tool; but if otherwise, let it be rubbed with a fine grit-stone; none better than the grindstone kind that is got on *Gatehead Fell*. After the barrel is bored or cleaned as above, let its inside surface be oiled over, which will prevent its immediate rusting; and if so preserved till used, will make a great difference in the first leather.

The tenons at the end of the branches, by which the whole column is to be suspended, will undoubtedly seem small and weak; but it is to be remembered, that the bucket I saw at *Aller Dean* hung by two parts of barely $\frac{3}{4}$ square each, that is 50 square eighths; whereas 4 Parts of 1 inch by $\frac{1}{4}$ are equal to 64 square eighths. After all, a column of 27 fathom and 9 inches diameter weighs but 2 tons, so that each part has only 10 cwt. to carry; therefore there is no doubt of their sufficiency, if good iron and well put together.

N. B. There is no objection to lengthening the mortices.

Ausloppes, 11th December, 1765.

J. SKEATON.

THURLSTON MILLS.

The REPORT of JOHN SMEATON, Engineer, touching the matter in dispute between Mr. RICH and Mess. WALTONS, concerning their mills at *Tburlston*.

AS no particular question has been formally stated to me in writing, I apprehend the matter in dispute to be reducible to the following, viz.

Whether Mess. WALTONS have done any thing, by the erection of their oil mill dam, which they have no right to do, and whereby Mr. RICH's corn mill may at certain times be affected, and stopped by back water?

As it will save many words, I refer to a sketch of the river and premises in question, hereunto annexed.

The rule that I have constantly followed myself in regard to the placing intermediate dams, whether for the erection of mills or navigations, and the same rule I have found practised by the best engineers and millwrights, and which is found generally subsisting in ancient mills. In flat countries, where levels are scarce, and consequently tail or back water most burthen some and annoying, is to build those dams so, that each dam shall not pen into the wheel of the mill next above, when the water is in it's ordinary summer's state.

This rule I apprehend to be founded upon the following reasons: that if the erection of a dam does not affect the mill above by tail-water, when water is the most scarce in dry seasons, as every mill that is well and properly constructed will clear itself of a considerable depth of tail-water when it has an increase of head and an unlimited quantity of water to draw upon the wheel; and as in freshes and floods, at the same time that they bring a quantity of tail-water upon the wheel, they also increase the head, and afford a superior quantity to be expended. This is looked upon to be the proper means, and equivalent, by which mills are to be cleared of back-water, as far as is consistent with the mutual enjoyment of those great benefits of nature, namely, falls of water; and that this alone is very sufficient, appears from hence, that, in common, mills will bear 2 feet of tail-water when there is an increase of head, and plenty of water to be drawn upon the wheel, without prejudice to their performance; but
mills

mills well constructed will bear 3 and even 4 feet and upwards of tail water ; I have seen an instance of 6 feet ; and it is a common thing in level countries, where (as said before) tail water is most annoying, to lay the wheels from 6 to 12 inches below the water's level of the pond below, in order to increase the fall of water, and, if judiciously applied, is attended with good effect.

If the rules above laid down are not decisive betwixt man and man, I believe it will be difficult otherwise to draw the line ; for while some may think 3 inches a sufficient clearance, others may think 3 feet too little ; and a third may subject himself to an action at law, after having been at a great expence and upon the best advice, for having done something to interrupt the free passage of the water 30 feet perpendicular below another's works, for there is no limits to fix the extent of imaginary evils.

I suppose it is a rule in the law, that no man can possess his own property in any new manner, that may be detrimental to his neighbour ; but then I suppose it is equally a rule, that no man can acquire an exclusive power over another's property, to prevent him from turning it to profit, in the same manner as the first had done before him. It would seem very strange and unreasonable, and also very detrimental to the publick service, (of which the benefit of mills and machines worked by water is so great as scarcely to be estimated) I say it would seem very strange, if I have an estate through which a river flows, to which no one has any controul but myself, in which there is 10 feet fall, and I have an occasion for a mill as well as my neighbour, that I cannot pen up the water to the same height as it before entered my grounds, and let it go at the same level as it used to depart, because the miller above says, that by keeping up this body of water within my ground, the water does not get away from his mill so freely in time of floods and freshes as it used to do ; and the miller below says, Sir, you shall not build a mill there, because I cannot have the water from the mill above I used to do, but will be intercepted by your dam. To the former I should answer, the water shall have the same passage into my estate as it always had, but I *absolutely deny* that you have ever had any right or occupation of a fall within my land ; it is true, I have not made use of it myself before, but as I always had it in my power to do so, as you have done before me, if my not doing it so long has been an advantage to you, you ought to thank me for having it so long, and not to think of precluding me from making the same advantage of the fall within my land, as you have done in yours.

To the miller below I should answer, you shall have the water delivered to you at the same level as before, and in the same quantity, for I neither intend to bottle it up, nor
divert

divert it from you ; but as I have the prior right of using the water passing my premises, this I shall do in the same manner as you will do after me.

Thus much by way of explanation of those principles and maxims that in my opinion either are, or ought to be, the medium by which disputes of this kind ought to be adjusted. If they are true and valid, as they appear to me to be, there is not the least foundation for a complaint from Mr. RICH on account of Mess. WALTON's oil-mill dam ; for it appears to be below the floor of Mr. RICH's mill-race no less than 1 foot 4 inches, and 10 inches below the bottom of the wheel, in the whole 2 feet 2 inches fall in the compass of less than 100 yards from the wheel complained of to be put in back-water by the said dam : on the contrary, had Mr. WALTON penned considerably higher than he has done, he would not, in my opinion, have infringed upon the true rules of mill-building, especially in such a country as this, where the river runs so rapid as seldom to lay any mill in back-water above three hours together, and scarcely ever above six, not even the wheel complained of.

It is observable, that Mr. WALTON's dam pens dead water a considerable way up Mr. RICH's goit towards the letter P ; but as this goit is without any floor laid, it may happen that a flood coming and washing in gravel, &c. may raise the goit's bottom, while it is above Mr. WALTON's dam's water ; or Mr. RICH, by clearing the goit, may at pleasure sink it below ; or the continual wearing of the mill's water may sink it below ; as therefore the bottom of an unfloored goit is of an uncertain level, nothing conclusive can be deduced therefrom : thus much however it is certain, that no part of the oil-mill's dam's water reaches any part of Mr. RICH's goit where any floor or setting is.

How far exactly Mr. RICH's premises extend down the river, I know not ; but according to the rules already laid down, if Mr. WALTON has penned the water so as to raise its surface against Mr. RICH's freehold, he has done what in my opinion he cannot vindicate ; it is however very manifest, that a considerable length of the tail of the jetty has at some time or other been taken off the river, as appears by the river's contracted breadth opposite thereto ; and if, by consent of the Lord of the Manor, he has obtained a right of making this fence for the more effectually keeping open his water-course, he has not thereby deprived the Lord of the Manor of the use of such part of the perpendicular fall of water, as Mr. RICH has not by prescription or otherwise obtained the use of ; for the sufferance of the Lord of the Manor, in letting a part of the natural fall of the river lay vacant, next below Mr. RICH's premises, must be considered in the same light as every other part of the unoccupied fall below.

I shall now proceed to a determination of this simple question, whether Mess. WALTON's oil-mill dam does or does not affect Mr. RICH's mill by back water, in any degree whatsoever, as they now both stand? In order to this it must be remembered, that the bottom of Mr. RICH's mill wheel lays 2 feet 2 inches above Mr. WALTON's dam water, that is, higher by 2 feet 2 inches than the water under the bridge when the oil mill-pond is full: the water therefore under the bridge must be risen 2 feet 2 inches before it comes upon a level with the bottom of Mr. RICH's mill wheel; and I look upon it as a certainty that Mr. RICH's mill would be going when the water was 18 inches higher than that, provided there were no impediments betwixt the bridge and mill, and the wheel itself properly constructed. Suppose then the water risen to that height under the bridge, that is, 3 feet 8 inches above the dam's height, in which case its mean depth under the bridge will be about 4 feet 8 inches upon 26 feet wide. Suppose now Mr. WALTON's dam away, and the water tumbling from the rock at E, in the manner it is said formerly to have done, still not above a certain quantity can be vented through the bridge at that given height, no more than can be vented over a dam at a given thickness, though unimpeded by any thing. According to my computation, the quantity that would be vented over the rock and through the bridge at 4 feet 8 inches deep, (supposing the dam away) would be vented over the dam, which is 84 feet in length upon the crown, at a depth of 2 feet $1\frac{1}{2}$ inch, or thereabouts. Hence it appears, that in this state of the river there will be a fall from the bridge into the mill-pond of $18\frac{1}{2}$ inches, at which difference the bridge and rocks will vent the same water as if the dam was away. This may appear somewhat paradoxical, to those unacquainted with these matters; but it is well known that a stream of water issuing from a sluice, or opening, will run the same quantity so long as it clears its tail, as if unaffected by tail water. At this height the balance is struck, and if at this height Mr. RICH's mill is not going, it must be owing to some impediments between the bridge and the mill, or to something wrong in the construction of the mill itself; at all greater heights the effect of the dam upon the water above is less, at all lesser heights it is greater; but if Mr. RICH's mill ought to go at the height above mentioned, it ought to go at all lesser heights, and if it will not go at lesser heights, it is very plain there is some obstruction between the mill and the bridge.

That there are in fact some obstructions, appear manifest from what JONATHAN LOCKWOOD the millwright alledged, that is, that Mr. RICH's mill was in back water before the gravel bed in the oil-mill dam was covered; if so, since no part of the gravel bed was above 9 or at most 10 inches above the dam's water when full, it will appear that Mr. RICH's mill is in back water, when the surface of the water in the oil-mill dam (below the rocks) is 1 foot 4 inches below the bottom of Mr. RICH's mill wheel: hence it appears, that very great obstructions are interposed betwixt the rocks and Mr. RICH's

RICH's mill wheel. Nor indeed does it need the evidence of **Mr. LOCKWOOD** to confirm this, the evidence arising from the things themselves being to me more strong, than that of any man living; for as soon as I set eyes upon **Mr. RICH's mill tail goit**, which is some distance below the covered part, not above $4\frac{1}{2}$ feet wide, and seems still less where covered; when I observed that both wheels delivered into the same goit, and the breast wheel in a very bad angle, as represented in the sketch, so that the breast mill stream must greatly obstruct the other; add to this, that instead of two small wheels of about 20 inches wide each, **Mr. RICH** has built one wheel of 5 feet wide, said to be able to drive three pair of stones at once, it is evident that the superior quantity of water necessary for this purpose, and the additional quantity necessary to be laid on after the tail water begins to touch the wheel; this again, added to the additional quantity also necessary on the same account to be drawn on the breast wheel, and this all crammed together into the same narrow goit that subsisted before the improvement; I say all this considered, it is very evident, that **Mr. RICH's mill** must be choaked with water for want of sufficient vent. But this is not all; for as the jetty or fence that divides the tail of the goit from the river, as it narrows the river from about 30 feet, which is about the general width, to 21 feet, this will cause the water to swell at least a foot in the contracted part of the river alongside the jetty, when the river is 3 feet 8 inches at the bridge above dam's height; and as the jetty itself, for about 60 feet above the tail, is not at a medium much more than 3 feet above the dam's water, it follows that before the water will rise to the height aforesaid, it will flow freely over the jetty for almost 100 feet upwards into the goit, and thereby fill the goit to nearly the same height as the water in the river abreast of the jetty, which, added to the obstructions before mentioned, must necessarily lay fast the over-shot wheel, long before the water rises to the height under the bridge above specified, according to **JONATHAN LOCKWOOD's** observation.

From what is above laid down it appears, that when the water rises 3 feet 8 inches perpendicular at the bridge above the dam, that then the dam has no obstruction, because the dam will then vent the water as fast as it could have been vented through the the bridge and over the rocks if no dam was there: but this supposes a free passage for the water between the rocks and the dam. How far the gravel bed at this height of the river acts as an obstruction, (the water being at that time not less than 79 feet wide across the gravel bed) is not easy to say, without seeing the river in that state, the obstruction arising from the gravel bed not being subject to computation on account of the irregularity of its figure: however, as it must add something, especially at lesser heights, I would advise **Mess. WALTONS**, for the sake of peace and good neighbourhood, (provided **Mr. RICH** will be contented therewith) to oblige themselves, on or before *Michaelmas Day* annually, so long as their dam shall remain where it now is, to remove all such gravel as shall be found

in their mill-pond below the rocks, and within the straight line from the south end of their dam, to the south side of the river where the rocks are, as shewn in the sketch *r s*, and to clear the same so that every part may be at least 8 inches below the top of their dam boards, and to lay the matter thence taken in such manner as not to be subject to get in the same place again. On the other hand, as it does not appear to me that Mess. WALTONS have done any thing but what they may justify; and further, that on the strictest examination it does not appear that Mr. RICH's mills receive any prejudice from Mess. WALTONS' works, but that the impediments found therein arise from the misconstruction of Mr. RICH's own works, I advise Mr. RICH, (if Mess. WALTONS will comply in removing the gravel bed as already specified) for the sake of peace and good neighbourhood, to be contented therewith, and drop all further prosecutions.

J. SNEATON.

Austhorpe, December 14, 1765.

HUBBERT'S MILL STREAM.

The REPORT of JOHN SMYTON, Engineer, concerning the power of HUBBERT'S Mill Stream to raise water.

HAVING examined the capacities of the water-way at HUBBERT'S mill, situated upon a branch of the river *Coln*, near *Drayton*, in the county of *Middlesex*, I found them as follows, upon the 23d of February, 1766: at which time the currency of this branch of the river was said to be nearly the same as it always is when the mills above, upon the same branch, are at work, or their waste gates drawn, by which means the quantity of water going down this stream is regulated.

	Cube Feet per Min.	
At <i>Hubbert's Mill</i> the discharge by a waste gate within the mill was	-	2166
By the water falling over the top of the waste gates without the mill	-	396
Total discharge in cube feet per minute		2562
	Feet Inches.	
The whole fall or difference at the mill was at this time	5	7

By the help of an hydraulick engine, properly constructed upon that head, and with the quantity of water above specified, the quantity of 356 feet cube thereof may be raised per minute to a perpendicular height of 20 feet above the level of the mill pond, which quantity amounts to 2517 hogheads per hour, accounting 52 ale gallons to the hoghead.

N. B. If the height is greater or less than 20 feet, the quantity will be inversely as the height.

It further appears on inspection, that the tail-water of HUBBERT'S mill (which stands upon a bye stream of the river *Coln*, as already mentioned) is nearly upon a level with the head water of LORD UXBRIDGE'S mill below, which stands upon the main river; and that the tail-water of HUBBERT'S mill being conveyed by a meandering course, a full mile in length, falls into the main river below LORD UXBRIDGE'S mill: hence it is to be inferred, that in the tail-stream of HUBBERT'S mill there is a fall from that mill to the main river equal to the fall at LORD UXBRIDGE'S mill, which being measured the same day was 5 feet 6 inches, the greatest part of which perpendicular descent may be added

to

to that of HUBBERT's mill-fall, without affecting any other; that is, by straightening, widening, and deepening the said tail-water course from the main river to HUBBERT's mill.

Now this being done in a moderate degree, will add 4 feet to the fall of HUBBERT's mill, and still leave 18 inches for the declivity of the tail-stream; in which case, the quantity raised will be greater than before; that is, instead of 2517 hogsheds raised per hour, the quantity of 4138 hogsheds will be raised in the same time; but by a still greater enlargement of the tail-stream to about a 15 feet bottom, brought upon a dead level at the depth of $11\frac{1}{2}$ feet below HUBBERT's mill full head mark, it is practicable to add 5 feet to HUBBERT's mill-fall, leaving only $\frac{1}{2}$ a foot declivity in the tail-stream, in which case the quantity raised per hour will be 4482 hogsheds.

At other heights the quantities that may be raised are expressed in the following table.

It is further to be noted, that, according to the information of the millers, the river *Coln* in the driest seasons is not less than half of what it was upon the day above-mentioned; so that HUBBERT's mill can then go at least half its time, and with the supply above specified; but by information that Mr. FORDYCE afterwards procured, they never are obliged to stop above 7 hours in 24.

The driest months, it seems, are August, September, and October, so that as the scarcest time for water is when there is the least occasion for it at *London*, and as we may reckon upon a constant supply during the winter and spring months equal to what is above set forth, that is, during all such times as the town is fully inhabited, it follows that we may, in effect, compute upon the same supply throughout the year.

The whole quantity of water current in the river *Coln*, at the time abovementioned, was ascertained, by observing that two waste gates at Lord UXBRIDGE's mill being drawn, at that time discharged the currency of the main stream, the dimensions of the openings of those gates being taken, the quantity of water issuing was from thence computed; this, added to the quantity discharged by the bye stream at HUBBERT's mill, constitutes the whole quantity, amounting to 10463 cube feet per minute, that is of 73978 hogsheds per hour, produced by the river *Coln*: the proportionable quantity thereof proposed to be taken into the new canal, is set forth in the following table, according to the different quantities that a different fall at the mill, and height to which it is to be raised, will be produceable of, and is contained in the last column.

A TABLE,

A TABLE, shewing the quantities of water capable of being raised at HUBBERT'S mill, according to the different heads or falls, and according to different perpendicular heights to which it is required to be raised.

Head or fall of water.		Perpendicular height to be raised above the mill head.	Quantity raised per hour.		Proportionable quantity taken to that of the river Coln, Feb. 23, 1766.	
Feet.	Inches.	Feet.	Cube feet.	Hogsheds of 52 ale gallons.		
5	7	20	356	=	2517	$\frac{1}{8}$ full
9	7	20	585.3	=	4138	$\frac{1}{8}$ full
10	7	20	634	=	4482	$\frac{1}{8}$ scarce
10	7	15	788.3	=	5573	$\frac{1}{3}$ scarce
10	7	10	1024.8	=	7246	$\frac{1}{6}$ scarce
10	7	$8\frac{1}{2}$	1125	=	7954	$\frac{1}{3}$ scarce.

London, March 10th, 1766.

J. SMEATON.

P. S. Four Hogsheds as above make a ton liquid.

CORN MILL at WORKSOP.

The REPORT of JOHN SMEATON, Engineer, concerning the practicability of erecting a Corn Mill, to be worked from the farm-yard pond, at *Worksop Manor*:

THE fall from the surface of the farm-yard pond to the surface of the canal, in the new menagerie, is 9 feet 6 inches, which is a sufficient fall for the erection of a mill; the principal difficulty, therefore, attending this affair, is to supply the said pond with water, sufficient to answer the intended purpose.

The quantity of water necessary depends upon the quantity of corn to be ground, which was stated to me at 10 loads per week, that is 30 *Winchester* bushels.

The quantity of water necessary to grind one bushel of wheat into flour, will grind five quarters of malt, so that supposing 10 quarters of malt to be brewed per week, the quantity of water that is necessary to grind 32 bushels of wheat per week will dispatch the whole business.

Now 3600 cube feet of water will, in this situation, be required to grind one bushel of wheat, and therefore 115200 cube feet will be necessary to grind 32 bushels; and this quantity, at least, must be supplied to the farm-yard pond in a week.

	Cube feet.
The overflowing of the pond at <i>Steetly</i> amount to, per week,	40019
A spring rising somewhat below, but which, together with <i>Steetly</i> overflowsings, may be brought to the farm-yard pond,	15120
The pipes from <i>Steetly</i> , at 5 hogheads per hour, which they are said to run, gives 1018 cube feet per day, $\frac{2}{3}$ of which I suppose will directly, or indirectly, come into the pond, amounting, per week, to	4751
The engine put in order, and the pipes repaired, as it now stands, will raise into the farm-yard pond per week,	24080
Total of the above, per week,	83970
The aggregate of the quantities before mentioned,	83970
The quantity required,	115200
Deficient	31230

The

The power 83970 cube feet is sufficient for grinding $23\frac{1}{2}$ bushels, that is, besides grinding 10 quarters of malt, it will grind $21\frac{1}{2}$ bushels of wheat, or about 7 loads; but this is not supposed enough, though there is no allowance made for waste.

Coldwell Spring, having been carefully levelled, has been found to rise 6 feet nearly higher than the surface of the farm yard pond, when that surface was $9\frac{1}{2}$ feet above the canal of the *New Menagerie*.

The course for an aqueduct has also been traced out, and though it will be almost 2 miles in length, yet this spring may be thereby conducted, upon a sufficient declivity, to fall into the farm yard pond.

Coldwell Spring being gauged in the month of March, 1766, then afforded 161280 cube feet of water per week, a quantity capable of grinding near 45 bushels of wheat; so that here we shall have 46080 cube feet of water per week to spare, or to allow for waste, and what the spring may afford less in dry seasons; but as it is said to be nearly the same in the driest seasons as when it was measured, we may safely reckon upon the whole quantity as above specified; nay, considerably more, because the defects will be more than made up, by taking in the brook that runs by the *Coldwell Spring*, which, at the time of measuring, was nearly equal to the spring, and in the driest season is said to run half as much; but if we reckon it only $\frac{1}{2}$ as much, viz. 53760 cube feet per week, we shall then have a surpluse upon the whole of 99840 feet per week, which is almost $\frac{2}{3}$ of the whole quantity found necessary.

Here, then, is a sufficient source of power not only effectually to answer the present purpose, but others also that may occur, and which in so large a family, may, in all probability, be very usefully applied.

As this spring is alone sufficient to answer the end, it would hardly seem a question which ought to be preferred; but as an aqueduct for *Coldwell Spring* will pass through rocky ground, in one part at the depth of 15 feet, and which, at a medium, will hold nearly $\frac{1}{4}$ of a mile, this, with some other difficulties, particularly the carrying it up the north lawn from the road, which being supposed a running sand, will be troublesome to dig, and will otherwise require arching; those impediments will induce a considerable extra expence; so that to overcome all probable difficulties, and to make the whole of proper dimensions and strength, will require the sum of 400*l.* to be expended upon it.

The deficiency of the former aggregates may, however, probably be made good by taking in the brook last mentioned: the particular observation was not made at the time, but, from the nature of the thing, it must be supposed that the water of this brook may be intercepted at such a level as to be conducted over the principal impediments that affect the *Coldwell* course, and consequently can be carried into the farm-yard pond, together with the water from *Steetly*, &c. now, if we reckon, as before, upon $\frac{1}{4}$ of the *Coldwell* quantity for this brook in dry seasons, we have 53760 to be added to the former aggregate of 83970, which together amount to 137730 cube feet per week, which affords a surpluse of 12530. This, however, is but barely sufficient to allow for waste, even if all the quantities held out in summer what they have been supposed from observations at the same time as those on *Coldwell Spring* were taken.

This aggregate scheme may probably be brought to bear for 150*l.* if not 200*l.* less than the *Coldwell* aqueduct; yet, as a material part of the supply depends on the performance of the engine, this, if out of order, will render the mill defective also. The certainty of success, therefore, attending the *Coldwell* aqueduct, and the permanency of the benefits arising therefrom, as depending wholly on natural causes, being considered, as every other part of the work will be the same, whichever way supplied with water, it seems that the value of 150*l.* or even 200*l.* saved in the first erection will no ways counterbalance the superior degree of certainty attending the other scheme, as well as the further advantages that may probably be drawn from a superior supply of water.

A further and substantial argument for executing the *Coldwell* aqueduct is, that by means thereof the whole of the waters mentioned may be *united* at a small addition of charge; so that by this means, exclusive of the engine, and after deducting $\frac{1}{4}$ of the whole quantity for waste, we shall have remaining a neat natural power of 240564 cube feet of water per week, a quantity capable of grinding $66\frac{3}{4}$ bushels, that is, above 22 loads of corn, being more than double the power required; so that, after serving very useful and valuable domestic purposes, in passing from the farm-yard pond to the canal of the new menagerie, it will there furnish a fine supply of water for the cascade in falling from the upper canal to the lower.

I have mentioned 400*l.* as the probable expence of an aqueduct from *Coldwell Spring* to the farm-yard pond, which sum is drawn from an estimate made from such observations as have already been collected, and is intended to give the best idea of the expence that I can at present: and I also reckon that the mill-work, together with building,

ing, the alterations that will be necessary in the farm-yard pond, and the drain that will be necessary for conveying the mill's water to the canal of the new menagerie, will cost 400*l.* more. If, therefore, it is not thought worth while to execute the scheme at the expence of 800*l.* I would not advise to proceed upon it; but if so, then I shall be ready to make such further observations as the former have suggested, in order to make out a particular plan of the whole, from which a more exact computation may be drawn.

J. SMEATON.

Newcastle, May 12, 1766.

SPURN POINT LIGHTS.

DESCRIPTION of the Machine for supporting the temporary Lights to be erected at the *Spurn Point*.

AB is the round pan, cage, or basket of iron, wherein the coal fire is made, to be 18 inches diameter, and 18 inches deep for the great light, and 16 by 16 for the lesser light, a little tapering towards the bottom.

CD is the mast for supporting the cage, at the height of 50 feet above the ground for the great light, and 35 feet above ditto for the lesser. The mast is hung up on an iron axis *EE* at the height of $22\frac{1}{2}$ feet above the ground, and consequently $27\frac{1}{2}$ feet below the center of the greater light, by means of which axis the fire-pan is brought down sufficiently near the ground to supply the same with fuel; the fire-pan turning upon an axis of its own or swivel, so as to keep it upright in every position of the mast.

F is the stone, of sufficient weight with the butt end of the mast, to balance the fire-pan, coals and iron-work at the other end, that it may turn freely, and in moderate weather be hauled down and up by hand of one man by means of two ropes, one fastened near the upper end, the other at the lower end of the mast, the stone to be hooped to prevent its splitting.

GG is a roller with winches, to which the ropes aforesaid being respectively applied with hooks for the more ready fastening to the staples in the roller, the mast will be managed in hauling down and up also by one man in the most stormy weather.

HH is a fixed piece of wood with a semicircular hollow, to which the lower end of the mast applies itself when in an upright position, and when necessary is retained therein by an half circular keeper, plate, or clasp of iron.

aa the great axis of the mast, is supported upon two upright posts 22 feet 4 inches above ground, and 3 feet within ground, framed into groundfills at the bottom, and each post braced in three directions; the feet of the braces to be framed into the groundfills, and all the bearings supported by piles underneath, disposed as per plan.

IK are the two upright posts.

I. M N

L M N are three braces belonging to the post *I*, and

O P Q are the braces belonging to the post *K*.

In order to keep the tops of the posts at a still more certain distance, the ends of the axis are to be finished each by a knob, to lay upon the outside of the bearing crutches or brasses, which will hinder the tops of the posts from flying out, and on the out ends of the knobs iron studs are to be driven into the top of the posts, which will keep them from coming together, the axis acting as a stretcher. The tops of the posts are to be hooped, the more effectually to fix the work thereon, and covered each with an iron plate to defend them from the hot cinders.

R is a pulley in order to set the rope at a proper distance for hauling down the mast by the windlass roll; this rope is to be annexed to about two yards of small chain fixed at the point *b*; such as is made for the smallest size of horse traces, will be strong enough.

S is an umbrella made of thin boards, to prevent coals, &c. from falling upon the person working at the roller, the pulley *R* is set at a distance in order that the rope for hauling down the mast may have the better purchase upon it when upright; where note, that this rope being fixed to the mast at *b*, when the pan is down, and the point *c* brought down to the point *e*, then the point *b* will come to the point *f*, and the tail of the mast will be at the point *g*, and the line *G g* will be the direction of the rope when it begins to act from the roller upon the tail of the mast, in order to hoist up the fire-pan, and set it upright.

N. B. The balance of the whole is to be so adjusted, that when the pan is full of coals, the head of the mast will be heaviest, but when the fire is burnt low then the head of the mast shall be lightest.

The same letters refer to the same thing in all the figures.

The measures set down in figures refer to the greater light, but the measures will be given for the lesser light, by taking off the respective parts from the scale belonging to the lesser, which will give every thing in proportion to their respective heights.

Directions for the smith.

It is to be observed that the fire-pan, with fork or crutch for supporting it, as well as all the iron-work at the mast head, is to be made as light as possible, consistent with the necessary

necessary degree of strength; $1\frac{1}{2}$ inch diameter will be sufficient for the two branches of the fork near their joining, and tapered to $1\frac{1}{4}$ near the holes for the axis on which the pan hangs, the rest in proportion; the whole to be made as short as possible between the top point of the wood of the mast and the axis, whereon the fire-pan hangs. It is also to be observed that the fire-pan axis projects 6 inches on a side beyond the ring, and that an iron strap be brought up from each side the bottom of the pan, and connected to the ends of the axis, as shewn in the front elevation, in order to prevent the axis from sagging by the heat of the fire. It must also be observed to make the round gudgeons of the fire-pan axis not above $\frac{7}{8}$ of an inch diameter in the round part, but the holes at least $1\frac{3}{8}$ or $1\frac{1}{2}$, and the gudgeons long enough that they may not jamb fast, or draw out by a little bending or sagging; one of the holes must also be made to open in order to change the pan occasionally, as repairs may require.

c c is the fire-pan's axis.

d d the two traps from the bottom.

EXPLANATORY Remarks and Observations upon the designs for building the Light-houses upon the *Spurn Point*, as approved of by the Honourable Corporation of Trinity-House, *Deptford Strond, London*.

No. 1. The general plan.

As the present variation of the compass at the *Spurn Point* is not exactly known, in case it should be found to differ from that supposed in this plan, viz. 20 degrees westerly, the direction of the light-houses in respect to one another are to be placed S. E. and N. W. by the compass, and the windows, &c. of the buildings to be placed according to the true meridian.

No. 2. The section and elevation of the great light-house.

The top of the stone setting or pitching of the foundation is herein supposed to be about 3 feet 6 inches below the general surface of the ground, from whence the height of 90 feet to the center of the lanthorn is taken; but as it is intended that the said setting shall rest upon the bed of gravel or shingle underneath the upper stratum of sand, the
depth

depth of the foundation may be a little varied, according to the depth at which the gravel is found, so as to give the foundation a greater degree of solidity. The length of the piles may also be varied if they cannot be got down to the length specified, or in case they drive too easily to that depth.

In the section, *A* shews a pipe or passage-hole for the sacks of coals, from the coal-vault to the lanthorn, to be drawn up by the machine *B*, which also serves for drawing up the sacks of coals that are brought in carts from the waterside into the door *F*, by means of the small gibbet at *C*, from whence they are to be poured down into the vault by the trap-door *D*, when filled too high, to open the door *E*.

G is a pipe for bringing down the ashes.

N. B. The jaumbs of the doors are supposed in the estimate to be of stone.

No. 3. Section of the lanthorn pipe room.

The receptacle for the ashes, both bottom and sides, for $4\frac{1}{2}$ feet in height, are supposed to be compleatly lined with plate iron of $\frac{1}{8}$ of an inch thick, to prevent the hot cinders and ashes from burning the wooden case; the door must be made as tight as possible.

Between the stone covers of the air tunnels *a a* other stones are to be introduced, though not shewn on the outside, so as to compleat a circle of stones, which are to be well cramp't together, in order to form a chain course for the springing of the brick arch thereupon.

B B are large bellows, to serve when the wind does not blow strong enough.

C is a tunnel and ash-pipe, for the speedy conveying the ashes and cinders to the outside of the bottom of the house, when the receptacle is emptied, as it ought to be every day.

D, air-holes in each face of the lanthorns, to be stopped or unstopped with sliders, in order to prevent the lanthorn from smoaking.

The hearth and floors of the lanthorn and balcony, together with the basement of the lanthorn, to be of stone; the roof and chimney to be of four-inch *Elland* edge flags, properly mitred together; the balcony rails to be of iron.

No. 4. Shews the plan of the lanthorn floor, and an horizontal section through the air pipes,

Where, in the plan, *A* is the passage or door-way up into the lanthorn, *B* the cover for the sack-hole.

At *a* is a hole for the rope to go down to the machine for hoisting the sacks, to be returned over pullies in the upper part of the lanthorn, so as to answer to the middle of the sack-hole.

b is a hole for a rope from the bellows, which, being returned in like manner over pullies, may go down into the pipe-room by the hole marked *c*, so as occasionally to be blown there as well as in the lanthorn, in case that in summer time the lanthorn shall prove too hot.

In the section, *C* shews the place of the sack-hole.

d is a multiplying wheel and axle for working the bellows with ropes instead of a lever, which in this place would be inconvenient, especially when the person working them is in the lanthorn, as in general he is supposed to be.

N. B. The bellows are supposed to be made square, in the way of organ bellows, but with neat's leather, and nailed together.

e shews the flat of a slider, and *g* is the same in its proper position; each air-pipe to have one, in order to open any of them at pleasure, and regulate the force of the wind when too strong.

N. B. In order to give the wind its full force, 2 or 3 of them to the windward to be open, and all the rest closed, and when the bellows are used, to be all closed.

No. 5. Plan and upright of one of the window-frames for the lanthorn,

Wherein the upright *A A* shews two of the upright pillars or stanchions to be of cast iron.

a a the fell, and *b b* the plating of strong iron bars, by which the pillars are connected; the window-frame is to be of wood, but strengthened by a bar of iron, laying within the middle horizontal bar, and screwed thereto, as represented in the plan at *c c c*.

No. 6.

No. 6. The section and elevation of the small light-house.

As this light-house is to be constructed upon similar principles with that of the great one, and the difference of dimensions being assigned by this general design, it is presumed that a more particular description of the parts will be unnecessary, when reference is had to what precedes and succeeds relative to the great one.

No. 7. Design for one of the ten iron stanchions that form the windows, and support the roof of the lanthorn, drawn at large.

This, with reference to what is explained concerning No. 5, will be sufficiently clear from what is upon the face thereof.

No. 8. Plan and section of the fire-cage and hearth.

This is supposed to be sufficiently explained with what is upon the face thereof.

No. 9. Plan of the foundation.

Upon the outward and inward circles of piles a kirb of wood is to be nailed down upon their heads, which are first to be cut level; but before the kirbs of wood are fixed down, the whole intermediate space between the piles is to be pitched or set with *Elland* edge setters, of 9 inches in depth, set edgeways, in the manner the streets are paved about *Hallifax*; those are to be well rammed down with a two-man rammer in the manner of a pavement, taking care that those setters that will be covered by the kirbs may be somewhat fuller than the pile heads, that the kirbs may take their bearings equally upon the setters as upon the piles: this done, the joints must be run full of grout, made of lime and sand made fluid with a proper quantity of water, which done the brick-work must be carried on thereupon as shewn in No. 2.

No. 10. Plan of the vault or basement story.

This is a plan of the vault at the top of the plinth or set-off above ground; the rest will sufficiently appear by reference to No. 2.

No. 11. Smith's shop floor and store-room floor,

Wherein the smith's shop floor *A* shews the great door, *D* the projecting landing-place, *E* the gibbet, *F* the machine or winch for hoisting the coals, *B* the hatchway for shooting the coals down into the vault, which being in the middle will be equally

distributed, *C* the hatchway for the sacks to go up into the lanthorn, answerable to the sack-hole or pipe described No. 2. *H* shews the place of the ash-pipe.

In the plan of the store room floor, *G* is the sack-hole, and *H* the ash-pipe, the east and west windows blank.

N. B. The doorway or hatchway had better be nearer the wall, as well in this as in the floors above.

No. 12. The dwelling-room floor and chamber-floor.

After what has been remarked on No. 11. it is only necessary to observe that there being two opposite chimnies in the dwelling-room, they may be used the one or the other as best suits the wind; in the chamber-floor the north and west windows are supposed blank.

No. 13. The upper chamber-floor and pipe-room floor

Will be sufficiently explained from what has been already remarked, the north and west windows in the upper chamber being supposed blank as in the chamber below, the pipe-room windows all open.

J. SMEATON.

The foregoing explanatory observations were sent to *London* for the approbation of the Corporation of Trinity House, a copy of which was by them returned, in order to be returned to Mr. THOMPSON in their Common Seal, to which was subjoined the following.

“ Trinity-House, *London*, March 21, 1767.

“ These explanatory remarks and observations upon the design or plan of the two new light-houses to be erected at the *Spurn Point*, the Master, Wardens and Assistants of the Corporation of Trinity House of *Deptford Strond*, do hereby, under their Common Seal, approve of, and do appoint the same to be carried into execution, pursuant to the act of Parliament passed in the sixth year of his present Majesty's reign.

By order of the said Corporation,

CHARLES WILDBORE, Clerk.”

ESTIMATE of the expence of building two Light-houses, with proper conveniencies, upon the *Spurn Point*, as designed by JOHN SMEATON, Engineer, from the orders and directions of the Honourable Corporation of Trinity-House of *Deptford Strand*.

Estimate of the great Light-house.

						£.	s.	d.
To casting, piling, and setting the foundation, as per plan,	-	-	-	-	-	123	10	0
To brick-work in the building,	-	-	-	-	-	482	13	1
To stone-work in ditto,	-	-	-	-	-	201	14	0
To carpenters work in ditto,	-	-	-	-	-	249	3	4
To iron-work in the lanthorn,	-	-	-	-	100	14	4	
To ditto in the balcony rails,	-	-	-	-	65	6	8	
To ditto in the fire-place, with 2 cages,	-	-	-	-	30	8	0	
To ditto in the building,	-	-	-	-	62	15	4	
						<hr/>		
Total of iron-work,	-	-	-	-	-	259	4	4
To plumbers-work, covering the balcony floor with lead,	-	-	-	-	56	19	3	
To ditto in cistern and pipes to bring rain-water from the roof,	-	-	-	-	15	6	0	
						<hr/>		
Total of plumbers-work,	-	-	-	-	-	72	5	3
To glazing the windows of the rooms,	-	-	-	-	5	0	0	
To ditto in the lanthorn,	-	-	-	-	12	5	0	
						<hr/>		
Total of glaziers-work,	-	-	-	-	-	17	5	0
						<hr/>		
Great light-house,	-	-	-	-	-	1405	15	0
						<hr/>		
The great light-house, as per estimate,	-	-	-	-	-	1405	15	0
The small light-house, estimated at $\frac{1}{2}$ of the expence of the great one,	-	-	-	-	-	1054	6	0
The stone platform between the two houses,	-	-	-	-	-	90	0	0
The brick wall round the greater light-house, 30 yards diameter, with carriage and small door, and capped with stone,	-	-	-	-	-	118	12	0
Ditto round the small light-house, 27 yards diameter, but being more exposed, estimated at ditto,	-	-	-	-	-	118	12	0
						<hr/>		
						2787	5	0
To the above allow for accidents, contingencies, and difficulty of situation, 10 per cent. upon the whole,	-	-	-	-	-	278	15	0
						<hr/>		
						3066	0	0
						<hr/>		

N. B. Nothing is allowed in the above estimate on account of supervisal.

London, February 21, 1767.

J. SMEATON.

This estimate was authenticated by the board, under their common seal, and with the following testimony :

“ This Estimate of the expence of erecting two new light-houses on the *Spurn Point*, the Master, Warden, and Assistants of the Corporation of Trinity-House of *Deptford Strond*, do hereby, under their common seal, approve of, and do appoint the same to be carried into execution, pursuant to the act of Parliament passed in the sixth year of his present Majesty's reign.

By order of the said Corporation,

CHARLES WILDBORE, Clerk.”

Trinity-House, February 21, 1767.

(Duplicate. C. W.)

ADDITIONAL Remarks and Observations, touching the construction of the Light-houses upon the *Spurn Point*, as approved of by the Honourable Corporation of Trinity-House, *Deptford Strond*, *London*.

Design No. 1. Being the general plan.

It is mentioned that the light-houses are to be placed at the distance of 300 yards center and center, and in a direction S. E. and N. W. by the compass, in respect to each other; to be joined by a platform of stone, the construction of which I proposed to be as follows :

To be composed of *Elland Edge* natural-faced flags, 2 feet in breadth and 4 inches thick; to be supported by a pavement or setting of brick on the edge, and 3 bricks lengths wide, to be well beat down with a paviour's rammer, the ground being first levelled and consolidated by ramming; the hand-rail to be $3\frac{1}{2}$ inches square, supported by posts of $4\frac{1}{2}$ inches and 6 feet long, set in the ground, so that the rail may not be more than 3 feet above the surface of the flagging. This timber is supposed to be of *Riga* fir.

The circular brick wall round the great light-house, said to be 30 yards diameter, that is, out and out, I propose to found at the depth of 3 feet, or thereabouts, below the mean surface of the ground, but if at a less depth, a stratum of gravel can be found tolerably compact to found upon it. The bottom, when opened, to be consolidated

lidated by ramming, and the first ground course to be 3 bricks length broad, set upon the edge, and driven down like a pavement; then two courses upon it to be laid flat-ways, as common, in mortar, of $2\frac{1}{2}$ bricks wide; then to be carried up of two bricks till a foot above the ground; then to be raised to 8 feet 8 inches high above ground, and to be capped with stone 4 inches thick: this, if the undertaker chuses, may be of *Elland* edge flagging, with the natural faces, but hewn true to a joint and regular border; or with any other kind of stone, such as used about the light-houses, that will bear the weather: the capping to project about 2 inches on each side, and to drip towards the outside, to be laid on with mortar made of lime from *Barrow*, in *Leicestershire*, or any other lime of equal quality for water-works. The body of the wall to be built with lime from *Houghton*, near *Castleford*, *Yorkshire*, or any other of equal quality.

The small light-house circular wall to be founded as the former, but the mortar courses on the 3 bricks length on edge setting; to be raised $2\frac{1}{2}$ bricks thick to 1 foot above ground, and then 2 bricks to 8 feet 8 inches above ground, and covered with 4 inch capping like the former, without any projection on the outside, and about 2 inches within, but laid so as to drip outwards, the outside brick breadth to be walled, and the capping to be laid on with *Barrow* lime, and the rest walled with *Houghton*, and both walls to be grouted or run with liquid mortar every four courses.

The area of these two courses between the light-houses and the out-walls should be paved with good bowlers, so as to resist the wheels of carriages carrying coals. This article has not been particularly considered in my original estimate, otherwise than in the articles of contingencies.

Design No. 2. Being the section and elevation of the great Light-house.

The external and internal circle of piles in the foundations are, as drawn, intended to be 10 feet long, and 10 inches diameter at the heads, and the internal piling of 9 feet long, and 9 inches diameter at the heads; but both these dimensions to be varied according as the ground proves on trying it with piles: the piles here supposed are of oak, elm, beech, or alder, but may be of *Riga* fir, or any other kind of red wood fir of equal quality for duration under ground, in which case, if square 9 inches will do for the kirbs, and 8 inches square for the internal piling, the length being supposed the same as before.

The thickness of that part of the shell of brick-work marked 2 feet, is supposed $3\frac{1}{2}$ bricks, and that marked 1 foot 7 inches of 2 bricks thick; the bricks in the north being

being made larger than those in the south, it was supposed they might probably in walling make those thicknesses specified, but at the same time it was not proposed to have bricks made on purpose, but to be walled with the common size of bricks usually made in that part of the country, but they should not be less than the statute thickness for *London*; and, N. B. wherever a difference in the dimensions of the bricks, the thicknesses assigned to the several parts cannot exactly tally; it is the outside measure which is to be preserved, unless particularly directed to the contrary. The sort of bricks proposed to be used is what in the north are called water-bricks, in contradistinction to stock-bricks, but those to be particularly hard and well burnt.

It was proposed to build the whole with *Houghton* lime, or other good stone lime of equal quality; but I am of opinion, that, considering the exposure of the situation, it will answer a better purpose to have the outside bricks in breadth walled with *Barrow* lime, leaving the undertaker to make use of what lime he chuses for the internal parts of the wall, being stone lime good in its kind, and well tempered; and that it will be better to allow the undertaker whatever difference there may be in the value of both sorts together, if any, when used instead of *Houghton* lime for the whole, than that this precaution should be neglected. The whole of the inside to be walled fair, and to be grouted at every fourth course. The undertaker to be allowed to use, if he pleases, either sea water, or such as can be obtained by digging a well upon the spot, as he shall chuse; and to prevent any damp in the dwelling-room it will be proper to be stoothed, lathed, and plaistered, (the plaister being made up with fresh water) which will be a far more effectual defence against damp, than any difference that can arise from the quality of the water in the out-walls, having found that good mortar binds as well with salt water as fresh.

N. B. This article of stoothing and plaistering was not considered in the original estimate.

In regard to the stone-work, all the parts that require large flat stones will be best supplied from *Elland-Edge*, or from *Cromwell Bottom* quarries, which are of the same quality; but in regard to the stone-work for door-cases, window-sills, steps, the air-pipe mouths, and girdle stones, to compleat and cramp that course together, with the mutules and fascia composing the balcony floor and basement of the lanthorn, as there are a number of good quarries in the neighbourhood of *Aire*, *Calder*, and *Dun*, as well as at *Sunderland*, which afford the proper materials, the undertaker should have the choice of getting them where he can serve himself with most advantage, being obliged to furnish good strong stone, and such as will endure the weather.

Instead

Instead of lintells on the insides of the doors and windows, they are proposed to be arched with brick.

The timber every where to be made use of is supposed to be the best *Riga* fir, or other red wood fir of equal quality, for the respective purposes, except where the sort of wood is particularly expressed to be of a different kind. The doors between room and room are proposed to be trap-doors, and the ascent between room and room to be strong step ladders of equal width with the door-ways, the sides to be at least 8 inches by $1\frac{1}{2}$, and the steps not to exceed 8 inches rise, and the ladders not to stand steeper than an angle of 45 degrees where the place will properly allow it.

The windows of the rooms to be of clean well seasoned *English* oak; they are designed to be simply a frame, whose outside circumference is 3 inches by 2, and the inside bars of stuff $1\frac{1}{2}$ by 2 inches; they are to be fixed up against a check made by the projection of the outward bricks, and fastened by a pin, so that the whole frame may be taken out at pleasure, in order to air and ventilate the rooms, when occasion shall require, and the weather admit: there is a small error in the original drawings, in regard to the manner of forming the window-sole stones, wherein the check is represented on the outside, and that, for the sake of keeping out and venting the wet, ought to be within; and as this matter cannot be so easily described in words as to prevent all uncertainty, I have added a drawing, intituled No. 14, wherein the particulars are expressed more at large. The glazing of all the room windows supposed to be of common glass; the clear opening of all the windows, when the frames are out, is 2 feet wide by 2 feet 6 inches high, the pipe-room windows excepted, which are to be 2 feet wide by 2 feet high.

Their number will be as follows:

In the smith's shop,	E. W. and N.	3	} All the rest blanks, with arches and sole stones to preserve the regularity on the outside, and to be opened afterwards, if need should happen to require.
In the store-room,	N. and S.	2	
In the dwelling-room,	E. W. N. and S.	4	
In the chamber,	N. and S.	2	
In the upper chamber,	N. and S.	2	
In the pipe-room,	E. W. N. S.	4	

Designs, being No. 3 and 4, being sections and plans of the lantern and pipe room.

Upon No. 3 I observe, that the windows may, with more advantage, be placed two course of bricks higher, or nearer the pipe mouth-holes, that above the proposed lining with plate iron; of the receptacle for the arches, it will, for further security, be proper

to line the whole inside of the wood-work, composing the upright tube, with double tin-plate, and to extend the same the breadth of a tin-plate within the air-pipes.

The stones mentioned to be laid between the pipe-mouth stones, marked *a a*, in order to form a chain course, are supposed to lay upon the same bed as the cap-stones of the air-holes, and to reach to the outside, wanting only one brick's breadth, that is, they will be 1 foot 6 inches up and down, and 1 foot 9 inches inside and out, at the extreme breadth: the whole of this course to be of stone of a firm quality, and double cramped upon the upper surface with cramps of 2 inches broad, $\frac{1}{2}$ an inch thick, and 14 inches long, and to be put in hot, and buried in a body of lead: the facia in like manner, composing the balcony floor, to be cramped with a double set of cramps fixed in the same manner, the joints thereof to be filled, and very carefully pointed with cement made of equal parts of *Barrow* lime, and pozzolano or smiths forge scales: the aperture or crown of the arch to be set round with an arched circle of stone of 9 inches thick, and the height of a brick's length.

The top of the balcony rails to be at least 3 feet 6 inches above the floor, and 3 feet high in the bars, which are to be of $1\frac{1}{4}$ inch thick, and 100-in number in the whole circle, and the upper and under circle connecting them to be 3 inches broad and $\frac{1}{4}$ inch thick; this circular railing to be supported by 20 studs leaded into the facia, and turned with a crutch at the top to take the lower circle of the railing without any other fixing thereto than the weight of the railing.

The lower fell of the lanthorn frame to be set in putty, made of white lead and oil, the upper fell of ditto to be covered with a kirb of wood bolted down, to be cut to a proper bevil for supporting the stone roof; this kirb to be oak; the chimney to be composed of five pieces, and to be ribbed with two strong hoops round the whole, of 3 inches head and $\frac{1}{2}$ thick.

N. B. It will be necessary to cut a small half circular groove under the facia, to prevent the wet from following the under side to the wall. The door in the balcony from the lanthorn to be of oak.

Designs No. 5. and 7. The former being a plan and upright of one of the window-frames for the lanthorn, and the latter a design for one of the 10 cast iron stanchions that form the windows, and support the roof of the lanthorn, drawn at large.

Upon

Upon which I have to remark, that the window-frames are supposed to be made of the best clean dry *English* oak, put together with white lead and oil, and glazed with the best crown glass, each frame to be fixed in place by 32 strong wood screws, and by two small bolts, that take the cross bars; and that all the iron-work, together with the screws, bolts, &c. and window-frames, are to be put together with white lead and oil, the whole being first painted twice over when tried together, and afterwards two coats when fixed in place.

Design 6. being a section and elevation of the small light-house.

Whatever has been or shall be observed regarding the great light-house, that will apply to the small one, is to be applied thereto, except what is particularly specified by the design or in writing to be otherwise.

The piles under this light-house are supposed to be of the same dimensions, and in number proportionable to the circumference of the circle of their respective bases, the stone setting between the piles to be of equal depth and solidity.

It now seems more eligible to make the room above the vault a store-room, and to put the two fire-places into the room above, in order to convert it into a dwelling-room, to be floored as the other.

The floors to be twelve-inch beams, and common joists 4 by 5.

The height of the mutules are intended to be 6 inches, and the height of the fascia 12 inches at the edge, and to rise $\frac{1}{2}$ an inch at the lanthorn, to be double cramped, as also the chain course at the air-pipe holes, as in the great light-house.

The number of windows in the small light-house as follows :

The room above the vault	N.	1	} The rest walled blank, with arches and sole stones, as in the great light-house.
The chamber and dwelling-room	E. W. N. S.	4	
The pipe-room	- - - E. W. N. S.	4	
Open windows		9	

N. B. The windows of the rooms and pipe-room to be of the same dimensions as the great light-house.

This light-house is proposed to be furnished with bellows of a proportionable size to those of the great light-house; but I apprehend the bellows in both light-houses may be omitted till it be seen whether the fire may not have a sufficient draught in calm weather by setting all the air-pipes open, without working the bellows, for unless they are necessary they may be cumbersome, and may at any time be added.

The sack-hole pipe is represented as broken off at top, not only in this elevation, but in that of the great light-house, the part of the arch wherewith it unites being that supposed to be removed from before the eye, but in reality those pipes are to be made to unite with the proper opening through the arch for the sack to pass through up into the lanthorn.

The balcony rails are, as per design, to be the same height, and the iron of the same thickness, as for the great light-house, but the number of bars to be only 80, the height of the lanthorn in the glass to be the same as the great light-house, and the cast-iron stanchions the same.

Design No. 8. is a plan and section of the fire-cage and hearth, upon which I have to remark, that it seems more eligible that the brick-work that supports it should be raised about a course higher, in order to bring the lower ring of the cage even with the top of the stone basement of the lanthorn; and N. B. the spaces between the eight pillars that support it are to be closed with milled plate iron $\frac{1}{4}$ thick; one side being made to open with hinges and a latch like a door, in order to clear the grate.

Design No. 9. is the plan of the foundation; to which I shall add, that the kirbs, being 10 by 6, are to be of oak, elm, or beech, but that the internal piles are, as already mentioned, to be varied in number, size, and disposition, according as shall appear upon trial by driving after the ground is opened: the foundation here specified being such as appeared proper upon such trials as were made in presence of the gentlemen of Trinity-House, *Deptford Strand*, when I had the honour of attending them there.

Design No. 10. being a plan of the vault or basement story, there is nothing to add but that the dotted lines upon the points E. W. N. and S. shew the places of four air-holes to ventilate and give light into the vault.

N. B. I apprehend it may be more eligible to make the entry-doors to open internally.

Design No. 11. is a plan of the smith's shop; floor to be flagged with natural-faced *Elland-Edge* flags, well jointed and laid; the two openings *B C* having a rebate cut round them, and to be covered with loose lids (with a ring in the middle) made of a double thickness of oak plank of $1\frac{1}{2}$ inch clinched together; the middle hole, though marked 3 feet, need not be larger than the other, viz. 2 feet 6 inches.

The gibbet *E* to be of oak, and to have a rope of a proper length, with guide pulleys for hoisting sacks of coals out of the carts, separate from the rope for hoisting coals to the top of the house, each rope to remain reeved, and ready to be applied to the barrel of the machine as occasion shall require; the machine to be made with an iron wheel and pinion complete*.

In the store-room floor the door-way, upon the whole, may, in this as the rest, remain in the place shewn in the plan; the beams to be 14 inches square, the joists 4 by 8, and the joists on each side the door-way to be 6 by 8.

Design No. 12. contains plans of the dwelling-room and chamber-floors, wherein it is to be remarked, that the girders lay alternately cross of each other.

In the dwelling-room is proposed two fire-places, that either may be made use of as the wind blows; the funnels are to be carried up in the walls, and lastly carried to the outside, and to be terminated like a cup by corbelling or oversetting the bricks near the top; those funnels to terminate at or about the height of the middle chamber-floor.

Before the chimnies are to be two hearth-stones of *Elland-Edge* natural-faced flags of $2\frac{1}{2}$ feet broad at least, and 5 feet long; each fire-place to be furnished with a grate or range set in stones that will bear the fire; the girders of the dwelling-room floor to be 13 inches square, and those of the chamber 12 inches square; the joists the same as the store-room.

Design No. 13. is added to shew the relative sizes and disposition of the floors, and seems to require no further directions than what is upon the face of it: the girders of the upper chamber-floor being 12 inches square, and those of the pipe-room 13 inches square; the common joists being 4 by 8, and the door-way joists 6 by 8, like all the other floors.

* The bellows and anvil are not supposed to be furnished by the undertaker.

The iron-work for hanging the doors as follows :

The double doors for carriages to be 9 feet clear width in each of the circular walls, to be hung upon well-made loops and crooks, not less than 8 lb. loop and crook together; the crooks to be leaded into stone inlaid in the wall, and the loops to be fixed to the doors with small screw bolts. These doors to be made with proper bars and fastenings to hold them open and keep them shut. The small doors in the circular wall $2\frac{1}{2}$ feet clear width, answerable to the platform from house to house, to be hung with loops and crooks of 5 lb. per loop and crook, and leaded into stone with proportionable latches and bars. The vault doors to be hung upon the same loops and crooks as those specified for the double doors of the out-walls, and fixed in the same manner, with each two bars or bolts of 4 lb. each bar, and a lock to each door. The entry doors to have the same loops and crooks as specified for the small doors in the circular walls, with each a lock, bolt, and latch of proportionable strength. The crane doors and balcony doors to have loops and crooks the same as the out-wall small doors, with each a bolt of proportionable size. The trap doors to the floors to be hung upon good HL hinges of at least 10, or T hinges of 13 inches, with one bolt of a proportionable size.

All the doors to be plain batten doors, except the two entry doors, which are supposed to be done with somewhat more neatness; all the out-doors to be of whole deal, and the trap-doors, on account of lightness, not less than $\frac{7}{8}$ thick when worked; all the doors and floors to be planed and shot clear of sap, and to be lathed, tongued, or rebated together.

The article of painting was not considered in the original estimate otherwise than by the general article of contingencies; but it is proposed that all the outside wood and iron work be painted with at least two good coats, which has not been already specified to be done with more; all the sash-frames with white lead and oil, all the iron-work with white lead and oil made of a dark lead colour with lamp black, and the doors, &c. with good red priming.

In respect to the lead covering of the balcony-floor (which was proposed to be done with lead of about 10 lb. to the foot) in case the joints are well cemented, as has been specified, I am of opinion, on reconsidering this article, that the lead may be omitted; and as the roof of the lanthorn and floor of the balcony will be greatly annoyed with soot and coal-dust, inasmuch that it is probable but very little of good fresh water can be collected, it seems that the lead pipe and cistern may also be omitted, and in lieu thereof that the undertaker furnish each light-house with a good stone trough or cistern, to hold

at least two hogheads each, properly supported on brick-work, with a cover to each, for depositing such fresh water as shall be brought from the main land ; and also to cover the hips of the lanthorn roofs with lead ; and as in the above articles of lead-work to be omitted, there will be a deduction of 72*l.* 5*s.* 3*d.* in the original estimate upon the great light-house, and 54*l.* 3*s.* 11*d.* upon the smaller one, it may be reasonably expected that those sums, making together 126*l.* 9*s.* 2*d.* will fully compensate every article of additional expence which was not fully considered in the first estimate, or has on this revision been suggested.

I beg leave further to observe to this Honourable Corporation, if they can admit both the light-houses to be somewhat altered from the places marked out in the plan No. 1, that is to go upon the same line about 80 yards more to the N. W. in order to bring the small light-house more out of the way of the seas in time of storms at high water, that it would be a means of preventing unforeseen expences in the protecting the out-works of the small light-house from the effects of such insults ; and this appeared to me the more desirable when I was upon the view of the temporary lights (in order to make an estimate thereof) as some derangements had happened to the platform and coal-yard near the small light-house by a storm happening at a great tide.

Austhorpe, May 9, 1770.

J. SMEATON.

The REPORT of JOHN SMEATON, Engineer, concerning the state of the Light-Houses building at the *Spurn Point*, under direction of the Trinity House, *Deptford Strond, London.*

THE beginning of December last I was at the *Spurn Point*, in order to view the state of the works carrying on there by Mr. TAYLOR, and found that the shell of the lesser light-house was erected, and the lanthorn compleatly framed, and set up and ready for receiving the glass, all the naked floors in, and the hearth erected ready for receiving the grate ; so that, exclusive of the balcony-rails, the glass, and inside finishing, this light-house may be considered as erected.

The foundation for the circular wall round this house has also been for some time laid, and brought even with the surface of the ground.

The

The great light-house was also then raised five courses of bricks above the second timber floor ; both which floors were in place, and the arch of the coal vault completed, as also the stone stairs up to the smith's room floor.

The height of the greater light-house above it's foundation was then 44 feet 6 inches, and near 40 feet above the ground, which is somewhat irregular.

The bricklayers were then at work, and as it is said there is seldom any frost at the *Spurn Point*, it is probable that the brick-work done in winter may become even more solid than what is done in summer. The brick-work of both houses is somewhat rough, but as Mr. TAYLOR seems very careful to have the courses properly grouted, or run with liquid mortar, I have no doubt of the firmness of the work, and which, at a very little distance, has all the effect upon the eye that can be expected.

On examining his stores upon the place, I found all the timber floors prepared, together with a large quantity of boards planed and tried up ready for the floors, doors, air communications, &c. so that I apprehend, taking the work done and preparations upon the place, as they appeared upon my view the beginning of December last, in part of the whole, that 1000*l.* in addition would complete the two light-houses according to the contract.

Mr. TAYLOR applied to me to have his extras settled, that is, the additional piles in the foundations, and depth of building, occasioned by the foundations being laid lower than the plan, and some other things that will be due to him ; but I told him that as there might yet be others before he had done, it might be as well to settle all the extras together ; to which he did not object.

Mr. TAYLOR has made a greater progress between the last and the former visitation than in any former period, and, if not cramped for men or money, I should expect to see the light-houses completed for use in the course of the present year.

The variation of the *Point* is become still more favourable to the present situation of the buildings than in my last representation.

Mr. TAYLOR remarked to me a new sand that the sea appeared to break upon at low water, being due east from the lesser light by the true meridian, and at about a mile's distance ; this I remarked to some of the gentlemen of the Trinity House on my return to *Hull*, on supposition they would more circumstantially inform themselves, and acquaint this Honourable Board therewith.

London, 29th March, 1774.

J. SMEATON.

REPORT upon the Lower Light at the *Spurn Point*, by JOHN SMEATON,
Engineer.

FROM a view of the works at *Spurn Point*, taken the 25th of April, 1776, it appears to me, that since my representation, by letter of the 22d of January last, the beach has considerably increased, not only in breadth but in height, and not only in the frontage of the low light-house and low temporary light, but for half a mile at least coastwise towards the north east.

Since then a cargo of *Hazlecliff* stone has been deposited at the foot of the low light-house, upon the bricks reported to have been there deposited in the said letter, none of which appear to have been stirred from their place; but as the cover of *Hazlecliff* stone is not fully compleated, I have now ordered a further quantity, in order to compleat the same. A great part of both bricks and stone are buried in the beach, that a more favourable course of wind and tides have brought before the work as above mentioned; so that, from the above state, it appears, that as things have taken that favourable turn that was wished, and hoped for as very possible, the low light-house and low temporary light are not now in the imminent danger that they appeared in in January last; and as there is now a greater appearance of probability that the lower light-house may become and continue serviceable for some years to come, I am of opinion, that the best way to turn the work out of hand, and to give it the best chance of continuance, will be to rebuild that part of the circular wall that the sea has taken down, and, to give it a greater depth and dimensions than before, to make good the ground taken away in the court-yard; that will then again be inclosed solid with *Hazlecliff* stone, and also to deposit a quantity of *Hazlecliff* stone round the circumference of the new wall outside, in the same manner as is now done round the foot of the building; and lastly to construct some grynes of fascinery, or stake and rice work, upon the beach, on both sides the building, in order to catch and detain the beach, in a manner something like what is practised upon the coast of *Suffex*, in the frontage of *Romney Marsh*, &c. This is what, from circumstances turning out favourable for the present, appears to me to be now adviseable. Yet the opinion will remain valid that is particularly expressed in the 7th, 8th, 9th and 11th paragraphs of the said letter of the 22d of January, and confirmed by the sketch of the gradual changes made in the *Spurn Point* since and including the year 1766, remitted in my letter of the 24th of January, viz. that the whole coast for several miles being in a considerable state of waste to seaward, the sandy beach composing the *Spurn Point* must follow it, and consequently the ground being taken away behind the light-house, it will be left an island, and therefore indefensible, but at much greater

greater expence than that of building a new house, even of the same construction ; but that, considering the fluctuating state of the coast to seaward, that it seems more adviseable to exhibit the lower light, whenever the present one shall fail, by means of a *machine light-house*, built upon the same principle as the present temporary high light, and that by way of provision for the constant exhibition of the lights, for the benefit and safety of navigation ; that, in the mean time, the present large temporary light machine. (as soon as those lights are ordered to be struck) be removed into the line as near the low light-house as shall appear convenient. This is the general sense and meaning of the paragraphs in the letter above referred to, and which still appear to me equally necessary now as then appeared ; but I now beg leave to add, that if the Honourable Board of *Trinity House, Deptford Strond*, shall think proper to order the rebuilding the circular wall, and the defences or out-works above mentioned, that it will then be impossible for the sea to render the light-house unserviceable so suddenly as not to give time to do some business. If it should be liked better, the large temporary light-machine may be taken down, repaired, marked ready for putting up again, and safely deposited under cover, ready to put up, whenever, by the sea's destroying the out-works, it shall appear adviseable and necessary ; but yet, as the timber and iron-work thereof have already been exposed for several years to the weather, it is my opinion that they will last as long, when exposed in the same manner, as if put under cover.

Austhorpe, 30th April, 1776.

J. SMEATON.

ESTIMATE for rebuilding the part of the wall of the low light at *Spurn Point*, that was taken away by the sea, and defending the same, as per Report.

	£.	s.	d.
To thirteen rods of brickwork, at 10 <i>l</i> .	130	0	0
To timber and piling under the foundations,	35	0	0
To <i>Hazlecliff</i> stone, inside the wall and out, 360 tons, at 6 <i>s</i> . 8 <i>d</i> .	120	0	0
To clearing foundations,	5	0	0
To gryne-work of fascinery,	10	0	0
	<hr/>		
Neat estimate,	300	0	0
To 10 per cent. contingencies upon the whole,	30	0	0
	<hr/>		
	£. 330	0	0
	<hr/>		

ESTIMATE

ESTIMATE for taking down, moving, and re-erecting the great temporary light, and placing the same in line of the other two light-houses.

	£.	s.	d.
To taking down, - - - - -	5	0	0
Removing, - - - - -	5	0	0
Repairs that may be wanted, - - - - -	15	0	0
New foundation, so as to be moveable, - - - - -	25	0	0
Re-erecting the same, - - - - -	10	0	0
Neat estimate, - - - - -	60	0	0
To 10 per cent. contingencies, - - - - -	6	0	0
	£. 66	0	0

Austhorpe, 30th April, 1776.

J. SMEATON.

ESTIMATE of what I have further ordered as necessary to compleat the light-houses at *Spurn Point*.

	£.	s.	d.
A copper funnel for the great light-house, to be fixed in the same manner as that of the low light, and of a proportionable size; this, after deducting the value of the present funnel, to be returned, - - - - -	18	0	0
To fixing, screws, bolts, &c. - - - - -	5	10	0
New cast-iron fire-hearths, possibly may come to about - - - - -	5	0	0
Some partitioning in the small light-house pipe-room, in order to make it convenient to lodge in; an addition to the ash-pipe; and several small jobs that I saw necessary, and ordered when I was there last, about - - - - -	6	10	0
	£. 35	0	0

Austhorpe, 22d January, 1777.

J. SMEATON.

The conclusive REPORT of JOHN SMEATON, Engineer, concerning the *Spurn* Light-houses.

IN consequence of Mr. TAYLOR's letter of the 30th of March last, acquainting me that every thing I had ordered, as well extra as contract work, was done, I visited the light-houses, at *Spurn Point*, upon the 7th of April, and finding that the capping of the detached circular wall of the lower light was completed, which for some months past had been the only thing wanted to the completion of his contract works, I gave him a certificate accordingly, of which I advised the Board by letter of the 20th of April; and also therein mentioned, that having staid the night of the 7th upon the *Spurn*, that the large copper funnel then fixed upon the great light-house completely answered the end, as the lesser one fixed upon the low light had done before, so that both lanthorns would go through the whole night, without any necessity for cleaning during the night; and that both lights appear exceedingly brilliant, and the heat within the lanthorns is proportionably less. These are, in fact, very great and essential improvements, both in regard to the light itself, and the advantage of keeping them, and therefore directly tending to keep the expence of maintenance as low as is consistent with the goodness of the light necessary to be exhibited, and which, as these light-houses differ materially in construction from any before erected, are matters that could only be adjusted by trial and experience, but which being once brought to bear, will be a model or example for the erection of others. On examination, I found that the grates I had ordered for the new hearths, being as much too small and narrow as the original ones were too large and wide, the light-keeper (being by trade a smith) had made one for the great light a medium between the two, which had answered, not only for the *Stone* coal, but for burning a mixture with the *Sunderland* coals, which, as the Board did not approve the disposal thereof, was become the more necessary; but the less lights grate being too narrow to burn the *Sunderland* coal, I thought proper to order another grate also for the lesser light, by means whereof they said they could burn one third of *Sunderland* with two thirds of *Stone* coals; and, according to this rate of consumption, they had as many of the *Stone* coals as would last till ~~Midsummer~~, (of which I took care to apprise Mr. CORTHINE, the agent,) and as many *Sunderland* coals as would last several years. Indeed the *Sunderland* coals are much in the way, as, by occupying the coal vaults, the *Stone* coals have been obliged to be lodged in the yards, and receive much damage by being exposed to the rains and the frosts.

I observed that a good deal of gravel and beach had been laid on before the lesser light, and that no material variation had happened in the Point; in short, that things appeared

appeared in as tenable situation in every respect, as they had done twelve months before, when I advised the rebuilding the wall; and though, according to the accounts I have since received from Mr. TAYLOR, more beach is still laid on, and matters appear still more promising, yet, as in the great storm at N. E. that happened in February last, the whole of the Hazlecliff rubble was dispersed from the S. E. side of the wall for 60 feet running; and though much pains and care appear to have been taken by Mr. TAYLOR in collecting and replacing the same from time to time, yet the total stock laid outside the wall has been upon the whole considerably diminished; and as storms of this kind must be expected every winter, and there does not appear to me, though a temporary defence, any thing more likely to be effectual, or to afford a better chance of saving the building for a term of years, without going into expences that cannot with any propriety be supported, as being greater than the expence of the building itself; I would therefore by all means recommend that for the present year 150 tons of *Hazlecliff* stone be got to the place ready to be applied as heretofore; that is, as it may be wanted; and as I have no doubt but that Mr. TAYLOR, while he remains an inhabitant of the *Spurn Point*, will not be wanting in his best endeavours to apply these stones to the best advantage for the defence of the buildings, I would advise the application thereof to be put under his management until Mr. CORTHINE can fall upon some more eligible person. Yet I must do Mr. TAYLOR the justice to say, that exclusive of such delay and disappointment as has arisen from other persons, that in his own person I think him strictly honest and industrious; and I apprehend it is very possible that after they have got into a way of using the stones in a lesser body, and occasionally as they are wanted, that 100 tons annually may suffice, I mean till an extraordinary revolution happens, for in that case I don't apprehend that 1000 tons would be effectual.

I have already acquainted the board that the high light machine being erected upon the line, it can in two hours be lighted, so that no damage can happen to navigation by any failure of exhibiting proper lights; and as the machine is placed upon ground walls, by continuing these walls, and getting the machine upon rollers, it can with great ease be drawn further within land, whenever the wearing away of the coast shall require it.

J. SMEATON.

Austhorpe, June 23, 1777.

P. S. The running out and shaping of the point itself was, when I was there last, much in the same state as it was in the year 1774.

The Report of JOHN SMEATON, Engineer, upon the state and condition of the low light-house at *Spurn Point*, pointing out the most likely means of preserving the same at a moderate expence.

IN the year 1766, I attended a deputation of gentlemen of the Trinity-Houses of *Deptford Strond* and of *Hull*, who were also attended by Capt. MITCHELL, who was supposed to know the coast the best of any body: he had preeviously set up marks for the placing of the light-houses, according to his own opinion; the line of direction was the same in which they now stand as to the points of the compass, but was more inland, that is, further from the Point than the line upon which the present buildings stand. It was then observed by the gentlemen, that the removal of the present light-house was on account of its being too far from the Point; and as the Point appeared to be increasing, and going out further and further yearly, that the new light-houses might not soon become again necessary to be removed and rebuilt, it was desirable to have them as near the Point as possible, as the probability was, that they would by the increase of the Point leave the houses more and more within the land. The only difficulty then seemed to be, whether the buildings could be so founded as to stand upright upon this great bed of sand, if built so much nearer the high water mark, upon which I said I could undertake to make foundations upon any part of the bed of sand, so as to enable the buildings to stand upright upon their bases, provided they were out of the way of the immediate stroke of the sea; and as it was universally allowed by all present that the land was increasing there in every direction, there could be little danger of a direct attack of the sea upon either building, and therefore the gentlemen ordered marks to be put down in the line on which they now stand, at the distance of 300 yards from each other, and which line was then only 115 yards distant from the extreme point at high water mark.

It was not till the year 1771 that the buildings were begun to be erected, when on revisiting the Point I found that it had so much increased in *length* that it projected at high water mark 280 yards further out than it did in the year 1766. The land had also increased on the side next the *Humber*, but had shewn a very apparent diminution to seaward. It had been determined to begin with the small light-house first, which being a less ponderous building, if any difficulty should arise in making a foundation, it might be a forewarning, and thereby furnish the means of conquering the difficulties that might attend the larger and more ponderous building.

Under these circumstances of the Point's having lengthened 280 yards in five years, it did not seem at all prudent to carry the line of the building further from the Point than had been directed, nor, on account of the diminution to seaward, to carry it further out; but finding room on the side next the *Humber*, I advised that they should be carried 80 yards further towards the *Humber*, upon the same line, than originally they had been proposed, and accordingly the foundation of the smaller light-house in question was laid 80 yards more inland than originally marked out, being there no less than 90 yards within land from high water mark, which seemed to be a very ample allowance for the incroachment of the sea, that hitherto was not supposed to be any other than casual, and that therefore in all probability would increase again on that side as well as the rest: I also on this account ordered the foundation of the building to be furnished with a greater number of piles than originally intended. Having never been at the *Spurn* otherwise than by water, previous to the laying the foundation of the lesser light-house, it was not till that building was considerably advanced that I had an opportunity of remarking the progressive effect of the sea upon the coast, which my frequent journeys by land during the progress of the work gave me an opportunity of seeing. In the year 1772 the great light-house was founded, and though there appeared no diminution of the land on that side, yet by way of precaution I advised it to be set only 60 yards from its first intended position towards the *Humber*, instead of 80, which kept it 20 yards further from the *Humber* than according to the former position, and also by way of further security, I ordered this foundation to have an additional number of piles in like manner as the former. During the carrying on of these buildings, I not only remarked that the sea was making gradual approaches toward the lesser light-house, but was wearing away the solid land of the coast for many miles to the north of the *Spurn*: however, its progress was not such as to denote any immediate destruction, till a great storm happening in January, 1776, that in two tides made such an incroachment upon the land as to take away the ground from under a part of the foundation of the circular wall, which occasioned one half of it to be beat down, and washed away the ground so as to lay bare a part of the piling upon which the main building stood; and had it not been for the precaution of the additional number of piles in its first founding, it most certainly had given way; however, there did not happen the least shrink.

On this alarming occasion, I defended the building with all the expedition that could be used by a large quantity of *Hazlecliff* rubble stone, forming a slope against the side of it to seaward, and in the advance of the spring the sea rather retreated than further wasted the ground. Seeing therefore, from the gradual wasting of the whole coast, that nothing could be a permanent defence to this building but what would defend it as an island, after the sea had taken the land away round about it, and as this could not be
done

done but at the expence of some thousand pounds, a much greater expence than what would erect a new building, I therefore advised, as the cheapest defence that could be made, so as to give it the best chance for a time, to rebuild the circular wall, founding it as deep as we were able at a moderate expence, and setting it upon piles, and surrounding the wall also with a slope of *Hazlecliff* stone, and, as a dernier resort, to erect the large temporary light machine in the line of the two buildings, 30 yards from the center of the smaller light-house more inland, and to repair and fit up the same ready for lighting, at two hours warning, so that in case any sudden or violent storm should render the house unfit for service, recourse could immediately be had to the machine light to continue the duty, all which was executed in the course of the following summer.

The beginning of the year 1777 there happened another violent storm at N. E. which the work sustained without any other derangement than that a part of the *Hazlecliff* stones laid on the outside of the wall was dispersed; therefore, after seeing the effects of this storm, I left it as my last advice, that "as storms of this kind must be expected every winter, there did not appear to me (though a temporary defence) any thing more likely to be effectual, or to afford a better chance of saving the building for a term of years, (without going into expences that cannot with any degree of propriety be supported, as being greater than the expences of the building itself,) than a proper application of *Hazlecliff* stones; I therefore recommended that for the present year (1777) 150 tons of *Hazlecliff* stones be got to the place ready to be applied as heretofore, that is, as it may be wanted, apprehending it is very possible that after they have got into the way of using the stones in a less body, and occasionally as they are wanted, that 100 tons annually might suffice, that is, till an extraordinary revolution happens, for in that case I don't apprehend that 1000 tons would be effectual."

At the same time I observed, that the high light machine being erected upon the line, it can in two hours be lighted, so that no damage can happen to the navigation by any failure of exhibiting proper lights; and as the machine is placed upon ground walls, by continuing these walls and getting the machine upon rollers, it can with great ease be drawn further within land, whenever the wearing away of the coast shall require it.

Austhorpe, 27th June, 1778.

J. SMEATON.

The REPORT of JOHN SMEATON, Engineer, concerning the situation of the Mills and Bleach Field at *Waltham Abbey* in respect of water.

THE bleach field is at present supplied with water, without diverting any water from the mills, as follows ; the ditches are filled by the water from the barge river, which in time of flushes rises high enough to fill them, which flushes are constantly twice a week in the drier seasons ; the water for washing is the water that continually makes its way down the barge river, and in the drier seasons, when the mills keep the water below the top of Sir WILLIAM WAKE's turnpike, the leakage thereof is found sufficient for the purpose, as I am informed.

When the navigation is diverted from its present course, and this turnpike rebuilt, or something in lieu thereof, to hold up the head of water for the mills, it is apprehended that the turnpike may then be made so water-tight, and the leakage thereof so small as not to change the water of the present barge-river with sufficient speed, to answer the purpose of washing the linens ; nor can the ditches be then supplied with water as they now are for want of the flushes.

But the ditches may be supplied with water by a bore running continually out of the *Waltham Abbey* mill-pond, and the washing may be supplied by a bore running continually (or in the day-time) from the new-constructed turnpike or flood-gate ; this will, however, so far as it goes, be a subtraction from the mill's water, but yet may be done so as not to affect the powder-mills at all, and the Abbey mills very inconsiderably ; on the other hand, it will be proved that both will be great gainers in point of water by the alteration.

Having, with the assistance of Mr. YEOMAN, Engineer, carefully viewed, measured, and calculated the quantity of water discharged at Sir WILLIAM WAKE's turnpike in the drier seasons for passing the barges, it appears to amount to considerably more than 14 * millions of cubic feet of water weekly, which, reduced to an average of the whole week, will amount to $1429\frac{1}{2}$ cubic feet per minute, flowing continually, and which would supply a bore or round hole in a plank of $23\frac{1}{2}$ inches diameter, whose center is 2 feet below the surface of the water in the head from whence it is supplied ; this is certainly a very great loss of water to the mills, and which must continue so long as the navigation remains in its present state, the greatest † part whereof will be saved to the mills jointly by the alteration.

* The number comes out 14,408,875 cube feet per week.

† The quantity expended by the new navigation will not be above $\frac{1}{3}$ part of the present to do the business.

Let us now examine what will answer the purposes of the bleach-field: having computed the quantities of water taken in for the supply of the ditches weekly, according to the information of the owner, I find it amounts to 140000 cube feet, that is at the rate of 14 cube feet per minute nearly, which will be supplied by a hole of $2\frac{3}{4}$ inches diameter, running constantly, made in a brass or copper plate of $\frac{1}{4}$ of an inch thick, and whose center is placed 1 foot below the surface of *Waltham Abbey* mill-pond.

The supply of water for washing, supposing it done in the open river, as at present, would be considerable; but as the width of the stream, when barges cease to pass that way, may, without detriment to the discharge of the flood water, be contracted at low water from 36 to 9 feet before the washing-stages, it will follow, that $\frac{1}{4}$ of the supply will produce the same velocity of the water in the river as at present, and consequently $\frac{1}{4}$ part of the leakage may supply it; but as the leakage of the new flood-gates may not be an 100th part of that at present, and greater or less according to the different states of repair they may be in, we will calculate what opening will supply, supposing no leakage at all.

The quantity necessary, when contracted as above, appears to be 135 cubic feet per minute, which will be discharged by a hole in a brass or copper plate of $7\frac{1}{8}$ inches diameter, the center being placed at 2 feet below the surface of a full head.

This quantity, with the former for the ditches, makes 149 cube feet per minute; but the quantity expended at the turnpike by the flushes being $1429\frac{1}{2}$ per minute, the quantity requisite for the bleach-field will be only betwixt $\frac{1}{5}$ and $\frac{1}{10}$ part of the water expended at the turnpike for navigation. Hence it appears, that upon the whole, at least eight parts in nine of the present water lost to the mill by the navigation will be saved, and yet the bleach-field amply served: hence, though the whole object of loss is trifling in proportion to the gain, yet there appears a method by which the waters gained may be minutely and justly divided; for if an additional bore be allowed the powder-mills, equivalent to the 7 inch bore at the turnpike, each property then will be equally benefited; for as the water of the bore taken from *Waltham Abbey* mill head would otherwise be drawn at the mill, there ought to be no equivalent to the powder-mills on that account.

The account therefore will stand thus: To avoid fractions, I will suppose $\frac{1}{5}$ part of the savings to go to the bleach-field, which being wholly deducted from *Waltham* mill, a $4\frac{1}{2}$ part will go to the powder-mill as its full due, and a $3\frac{1}{2}$ part to *Waltham* mill.

The *Waltham* miller on this occasion, as usual, may not think he has his due, because he will not get in the very same proportion as his neighbour; but let us examine what he will get, and then his right to complain will be better judged of.

When I measured the mill's draught of water on Wednesday the 13th instant, I found the mill expending at the rate of 1087 cube feet of water per minute, and, as the miller said, was capable with that water of grinding and finishing about 4 bushels of wheat per hour; and he further said, that in short water times he frequently had not the average of that water to go constant for the whole 24 hours; the quantity saved will therefore be as follows :

The average of water expended by the navigation per minute being $1429\frac{1}{2}$	
cube feet, and the half of this being supposed due to Sir WILLIAM WAKE,	Ft.
will be	714 $\frac{3}{4}$
From this deduct the whole water for the bleach-field,	149
Saved to the miller by the alteration, besides supplying the bleach-field,	<u>565$\frac{3}{4}$</u>

Which appears to be more than $\frac{1}{2}$ of the water that he is in dry seasons possessed of, and sufficient to make an addition to his grinding of 2 bushels an hour constantly; so that instead of being injured, he will be greatly benefited.

But as some water will always leak at the turnpike, and as it is probable springs arise in the channel of the river, I apprehend a bore of 6 inches, at 2 feet under the top of the turnpike, will be a sufficient supply for the washing, and the equivalent will be most properly adjusted either by applying a new opening, or by widening the present one. at the lowest orifice belonging to the powder mills. The size or widening of the present opening, if that method of adjustment is approved of, I shall be ready to compute.

London, May 16, 1767.

J. SMEATON.

N. B. The computation of 135 cube feet for the bleach-field washing, is computed upon a supposition of the waters moving 10 feet per minute in a channel of 9 feet wide, and at an average of 18 inches deep.

REPORT on *Waltham Abbey* Powder Mills, respecting navigation on the river *Lea*.

WE, whose names are underwritten, having, the 27th of February, 1771, inspected the powder-mills of *Waltham Abbey*, belonging to BOUCHIER WALTON, Esq; as also the several works of navigation from *Rammy Mead* lock to *King's Weir*, upon the river *Lea*, in order to examine how far the said mills are, or may be, affected by the said navigation works, are of opinion as follows.

1st. That the said mills are considerably affected in their going when the water is held up by the new stop, called *Waltham* stop, so as to make more than 3 feet, which is esteemed navigable water, upon the threshold of the lower gates of *Waltham* lock.

2d. That the said mills are affected, though in a less degree, even when there is 3 feet, and not more, of water over the lower gate threshold of *Waltham* lock.

3d. We also observe, that the said mills are affected by the water-course leading from the said mills to the river, being not sufficiently clear of gravel, weeds, &c.

4th. It appears that the said mills become also affected by the passages for the water at Mr. WALTON's weir, called the corning-engine weir, not being sufficiently ample, in consequence of the circumstance above mentioned.

Upon the foregoing matters we propose and recommend as follows.

1st. That a stone should be firmly put down in a conspicuous place near *Waltham* stop, to mark the height of 3 feet water upon the threshold of the lower gates of *Waltham* lock, and that the keeper of the stop should have strict orders from the Commissioners of the navigation at all times to draw the gates of that stop, so far as to prevent the water rising there at any times above the said mark, unless requested for the sake of navigation to the said mills, or the town of *Waltham Abbey*, and unless in time of floods, when all the gates being drawn will not prevent it.

2d. After Mr. WALTON has cleared the obstructions in the water-courses leading from his mills to the river, that what obstruction to the going of the mill still remains, be relieved by enlarging the water-way at the corning-engine weir, which we are of opinion will be done by an additional conduit or passage of 10 feet wide, its floor to be

be laid as low as the floor of the said weir, and to be furnished with a draw-gate or pointing doors to pen the water occasionally, so as to enable the barges to pass to the mills as at present; and as this enlargement can only become necessary by the water being pent at *Waltham* stop too high for the powder-mills, even at 3 feet above the lower gate fill of the said *Waltham* lock, we are of opinion that this alteration should be made at the expence of the navigation.

Having also inspected JONES's turnpike, we found it not only out of repair, but materially defective, as the gate could not be shut down within some inches, and thereby a great quantity of water suffered to go down the old barge river, to the detriment of the mills aforesaid, as well as others dependant on the said head of water. Respecting which we are of opinion, that the said turnpike should be kept in good repair, on account of the said mills, and that the particular defect of not shutting down should be remedied as soon as possible.

We are informed, and believe it to be true, that the bargemen going downwards, after having passed the aqueduct lock next *King's Weir*, and taken the quantity of water necessary for passing them through the same, frequently draw a further quantity to keep them forward, by which means an unnecessary quantity of water is brought down the canal, whereby the said mills are not only detrimented by the loss of water, but the navigation itself; for besides impairing the banks of the canal, the current that helps barges going down obstructs those going up: it seems therefore necessary that proper orders should be given to the person having the care of the new stop of *King's Weir*, or otherwise to prevent these abuses.

London, March 27, 1771.

J. SMEATON.

THE REPORT of JOHN SMEATON, Engineer, upon the state of the river *Lea* navigation, so far as the mills abreast of *Waltham Abbey* canal are affected thereby.

APRIL 3, 1779, at the desire of BOUCHIER WALTON, Esq; owner of the powder-mills at *Waltham Abbey*, I viewed the state and condition of the river *Lea* navigation, from and inclusive of the lock upon the cut next below *Waltham Abbey* cut or canal, up by the course of the said canal to *King's Weir*, and found the same as follows:

All the locks constructed without walled chambers, by which means not only much more water is necessarily expended at each lock for the passage of every vessel, but the passage of the vessels themselves are proportionably retarded by taking more time to fill and empty.

The head gates of all the locks within the above district were so considerably leaky, against which the water ought constantly to lay, except during the time of vessels passing, that I could not estimate the constant leakage at less than one of Mr. WALTON's mill streams, which in consequence in all dry seasons is lost amongst the three sets of mills abreast of this cut, viz. *Enfield* mills, *Waltham Abbey* powder-mills, and *Waltham Abbey* corn-mills, and which waste of water also retards the passage of the vessels, and which retardation, as well as waste of water, is also increased in case the tail gates are out of order, as I have reason to suppose they are, the tail gates of the lock near the head of the cut next below *Waltham Abbey* cut, which was the only lock through which I saw any vessels pass were very much so.

The wastes of water above specified, though very material to the mills, are yet very trifling in proportion to the waste that will be occasioned, in case what I was informed of be really the practice, as I have reason to believe it is, viz. that vessels going down very frequently, if not always, after the lock is emptied, and the vessel is let down to the level of the lower canal, draw the cloughs or flakers of the head gates, and leave them both running a full bore of water, the same as while the lock is filling, in order to make a current down the cut to ease the horses, and help them forward upon their passage; and leave them running without returning to shut them, so that in fact they run till some other person has occasion to shut them, and during this time, which is indeterminate, a considerable portion of the whole river when water is scarce will pass this way, and be lost to the mills abovementioned; it being a rule that what is lost at one lock, will also be lost to all the rest upon the same canal, or head of water. This is a practice that ought by no means to be suffered, as besides a damage of indeterminate magnitude to the mills,
it

it is a very great and manifest detriment and hindrance to the navigation itself; because whatever small benefit it may be to the ease of passage of vessels going down, it will be a greater hindrance to vessels going up; and when it happens, as must frequently be the case, that when any of the reaches of the canal or heads of water are drawn down from above, the vessels going up will be prevented navigating through the same, and must wait till those reaches are filled, by letting the water down from above in the canals, or till supplied by the currency of the river *Lea* in the open river; which hindrances to the navigation itself very greatly surpasses any advantage that can be drawn from the flashing of the vessels downwards.

These evils therefore are worthy of remedy merely for the facility of the navigation itself, but as relating to the mills, which can only have the surplusage, will be very destructive in dry seasons; and, I believe I may take upon me to say, very contrary to the idea wherewith the improvements were first framed before the last Act of Parliament was applied for.

For remedy whereof, as far as regards the first, viz. the wharfing up of the lock chambers, it is very difficult to be done now in a substantial manner with brick, as it will occasion the stoppage of the navigation for the time; but they may be wharfed up with piles, planks, and land ties, keeping the navigation open; and where any of the locks so far fail as to need the water to be taken off, they may be wharfed with brick, as, to be substantial, they should have been done at first.

2d. As the mills are more immediately hurt by the leakages of the lock gates, than the navigation, the mill owners and lessees should have power to repair the leakage of the gates, and charge those repairs to the trustees of the navigation, in case they do not do it on competent notice given by the respective millers.

3d. The practice of flashing I do not see any adequate remedy to prevent, but by having a man or lock-keeper to attend each lock, by which the mills can be affected, with a proper hut to screen him from the weather; and two men will be necessary in case the navigation is unrestrained to all hours of the night; which men, as they become necessary by the misapplication of the bargemen of the proper mode and utensils of navigation, and being also for the benefit of the navigation, should, as it seems to me, be paid by the navigation, or a tax laid upon the bargemen; but being for the security of the millers, should be chosen or dismissed by the mill owners or lessees immediately interested. Those men (it being made their duty so to do) will prevent much wear and tear in the use of the locks, and by attending to keep the respective heads of water constantly.

stantly full, with as little waste as possible, will thereby save much more time to the bargemen in the course of a voyage up and down, than they can possibly gain by any misapplication of the water.

I must also observe that the banks in many places are too low and too weak, so that when the water goes over them it cuts them down in gullies, and this will necessarily, during the continuance thereof, occasion an extraordinary waste of water through the whole of such canals.

I also viewed the old turnpike, called Sir WILLIAM WAKE's turnpike, which, before the navigation was altered, was used as a pen of water, by means whereof, and through which the navigation passed, but now is of no other use but to open in time of floods, and to be kept shut at all other times, to pen up water for the service of *Waltham Abbey* powder-mills, and corn-mill, as heretofore, and which for that reason should be kept free from unnecessary leakage. When I saw it, by temporary repairs, it was sufficiently tight; but as it appeared to me, its main timbers and general state of repair and strength, was so much impaired that I should not be surpris'd if the first great flood of the *Lea* should take it away, in which case both the sets of mills at *Waltham Abbey* would be deprived of their water; it therefore seems, that though it is by law to be repaired at the navigation's expence, yet being no longer necessary thereto, it would be proper for the owners of these mills to take the rebuilding and future repairs upon themselves upon a moderate allowance from the navigation.

J. SMEATON.

Austhorpe, April 17, 1779.

To the Trustees of the River *Lea*.

The REPORT of JOHN SMEATON, Engineer, respecting the alterations made at *Sewardston* mill, so far as they concern the quantity of water taken from the river *Lea*, as also the loss sustained by *Sewardston* mill by an alteration made at *Enfield* lock in the year 1781.

HAVING received no commission from the Trustees of the river *Lea* to determine any thing betwixt parties, I take the opportunity of reporting my opinion, as a professional man, upon the premises.

On Saturday the 26th of October last I carefully viewed and examined the mill of *Sewardston*, as also the present state and condition of the gage sluice called *Enfield* lock, by which water is taken to *Enfield* mill.

Respecting *Sewardston* mill, and hearing what is alledged and agreed on both sides, in point of fact, is, that it has undergone no alteration except that of laying the floor of the corn-mill conduit lower, and the construction of the water-wheel correspondent thereto; that the fell or threshold over which the water issues, as well as the width of the gate, remains the same; this alteration, therefore, I am of opinion, will have the effect of grinding more corn with the same quantity of water, but not of requiring more water to grind the same quantity of corn, and to the height to which a miller may lift his gate or shuttle, I can conceive he can be under no restriction.

The mill being tried in my presence, with a full head of water, it appeared to dispatch at the rate of upwards of 100 quarters of wheat per week.

I also took an admeasurement of the quantity of water used while working at the rate abovementioned.

I examined the present state of *Enfield* lock, being now restored to its former state before the alteration, and to the satisfaction of Mr. WHISLER; and comparing this with a model produced by Mr. WHISLER, and afterwards authenticated by Mr. NICHOLLS, as carefully made by him from measures taken at the time when the water was diverted into *Enfield* cut, in favour of the navigation in a greater proportion than formerly; I say, comparing this model with the state of the lock as I found it, it appears to me, that there would go into *Enfield* cut or mill river at that time considerably more water (over and
above

above what ought to have gone through the proper gage) than was taken by *Sewardston* mill to grind above 100 quarters per week, as above specified.

But as at the time of the complaint the waters ran so short that it was impossible to have kept up his mill-head to the height I saw it, and therefore could not have ground the same quantity of corn with the same quantity of water, Mr. WHISLER lays his account in his ability of only dispatching 50 quarters per week had the water been undisturbed; but reduced in the manner it appears to have been, he actually dispatched but 20 quarters per week, thereby losing *bonâ fide* 30 quarters per week of what he might, and would have done, agreeable to what he has stated in his case of the 14th of February last, addressed to the Trustees of the river *Lea*.

As therefore it does not appear to me that Mr. WHISLER has made any alteration that enables him to take more water than he is entitled to; and as there does not appear any thing that shall cheque, so as to reduce the quantity of grinding lost per week, but rather that from the above circumstances Mr. WHISLER's statement of 30 quarters per week appears probable and well founded, I therefore see nothing that ought to hinder the admission of that quantity lost per week.

The whole length of time stated in Mr. WHISLER's case of 12 weeks and 5 days I don't find controverted, which he reduces a fortnight on account of the time the gages were shut down for cleansing the navigation; but as during this time he would have the whole water of the river *Lea*, he would be enabled to maintain a full head, notwithstanding the driness of the season; and therefore in that fortnight could dispatch above 200 quarters, that is, above 100 quarters more than the ordinary rate for a dry season if the water had been divided betwixt *Enfield* mill and himself, as usual. This 100 quarters will therefore compensate the loss of 30 quarters per week for three weeks and two days, which, applied as a further set off, will reduce the whole time that the loss of grinding continued, to seven weeks and three days.

Respecting the rate at which he charges the loss of grinding, viz. 9*l.* per week upon 30 quarters; that is, at the rate of 6*s.* per quarter, or of 30*s.* per load, a price that I apprehend to be very far beyond the ordinary accustomed price of grinding in that district of country.

This is not to be doubted, that about the time of the hindrance mentioned, there never was known in man's memory so great and long-continued a drought, and therefore all mills being short of water, there would be a great want of meal at the *London* market, and

and those who ground their own corn (as it is alledged Mr. WHISLER docs) and could get it to market, would doubtless get extraordinary profits; but as on this head no evidence was laid before me, and it being a mere matter of traffic no ways determinable by rules of engineery, I must of necessity refer this point entirely to the Trustees, to satisfy themselves by such evidence of the fact at the time, as shall further occur, or be laid before them.

It has been observed to me, that the mouth of the mill-stream of *Sewardston* mill has been widened, contrary to a clause in the Act of Parliament, which allows that every part may be made wide enough for navigation to *Sewardston* mill, which widening, on the other hand, has been denied *as to the mouth*; I can therefore only say, it is of little consequence to the navigation of the river if wide enough at the mouth for a barge, and there is no restraint as to the depth. This restriction as to the mouth seems to have been introduced as a security to *Enfield* mill, that drawing from one common pond above *Enfield* lock, *Sewardston* mill should not get more than its share.

Austhorpe, November 12, 1782.

J. SMEATON.

To the Trustees of the river *Lea*.

The REPORT of JOHN SMEATON, Engineer, respecting the loss of grinding sustained at *Tottenham* mills by the leakage of the lock gates, from the year 1778, till April, 1781.

HAVING received no commission from the Trustees of the river *Lea* to determine any thing betwixt parties, I take the opportunity of reporting my opinion, as a professional man, upon the subject before me.

Being favoured by Mr. WYBURD with the state of his demand upon the Trustees of the river *Lea*, I find it consisting of various articles; but so far as my judgment may be supposed to be of use upon the same, it must be in those articles containing a charge for loss of grinding at those mills during a term, from the year 1778, to the 2d of April, 1781, occasioned by a needless loss of water, arising from the disrepair of *Tottenham* lock during that time.

In this account Mr. WYBURD particularly states the loss from the 30th of October, 1780, to the 2d of April, 1781, according to notice given to the Trustees of the loss he then supposed himself to be sustaining, viz. at the rate of 5*l.* 10*s.* per week.

The whole time intervening being 22 weeks, from this he deducts 7 weeks that he was fully supplied with water, there then remains 15 weeks, wherein water was lost in that period, which, charged as above, amounts to 82*l.* 10*s.*

No evidence was adduced to invalidate Mr. WYBURD's charge respecting the length of time as above; and it was very satisfactorily proved, that not only during that particular period, but for two years before, the lock-gates and flakers had been exceedingly leaky, and out of repair, and also had been misused, and great quantities of water expended to flash boats over a shoal, that had remained in the tail of the cut ever since its first being opened, till deepened 20 inches by Mr. GLYNN, in April, 1781.

Mr. WYBURD being desired to exhibit some testimony, whereby it might appear that his charge of 5*l.* 10*s.* per week was properly founded, Mr. BASS, his present millwright and foreman, alledged, that it was the general opinion of himself and millers, that

that the leakage of the lock-gates was as much as would drive one pair of stones. In further testimony Mr. WYBURD produced a paper, said to be extracted from his books, at the desire of one of the Commissioners, by which, comparing what the mills had done for 12 weeks after the 20th of June, 1780, with what they did in the same period succeeding the 20th of June, 1781, after the lock had been repaired, he finds they did more by $30\frac{1}{2}$ quarters per week in the latter year than the former, though it must be acknowledged the year 1781 was a dryer year than the year 1780.

He states, that in 12 summer weeks, 1780, they ground 1029 quarters			
average, per week,	-	-	- $85\frac{3}{4}$
Ditto,	-	1781,	1395 - $116\frac{1}{4}$
Difference lost is			Q ^r $30\frac{1}{2}$

Upon which (as a fact) Mr. WYBURD reasons thus: if, when we ground 85 quarters per week we lost 30, in grinding double that quantity they must have a double loss, and in a triple quantity a triple loss, and so on till they came to five times as much; so that when their grinding amounts to 5 times 85, or 425 quarters per week, their loss amounts to 5 times 30, or 150 quarters.

The different grindings being therefore averaged thus:

1	85	lost	30
2	170		60
3	255		90
4	340		120
5 times	425		150

divide by 5) 450 (90 quarters per week will therefore be the average loss, amounting to 18 loads, which, at 7s. 3d. per load, amounts to 6l. 10s. 6d. per week.

Now Mr. WYBURD, in reasoning upon the fact above stated, takes it for granted, that because a greater head of water which enables them to grind *more* corn, produces also *more* leakage, he supposes them proportionable, so that when they can grind five times as much corn, there is five times the leakage; but this is a very evident mistake, for if with a 6 feet head, and suitable follow of water, they grind 425 quarters, the leakage through the same apertures, will only increase beyond what it would be at the ordinary summers head of 4 feet 4 inches by $\frac{1}{3}$ part of the whole, so that if, upon grinding 85 quarters, they lose 30, upon 425 they will only lose 36, and the average loss will not exceed 33 quarters per week, that is, 6 loads 3 quarters.

Mr. WYBURD's mode of reasoning upon the subject, he seems himself apprehensive, if pursued to its extremity, was leading him into an incongruity, for, says he, "when we grind 500 quarters per week, we don't mind the loss of water so much," that is, though when grinding 425 they were reckoning themselves to lose, and ought to be paid for 150 quarters, amounting, at the above rate, to 10*l.* 17*s.* 6*d.* per week; yet, when they could do 75 quarters more, and, according to the same scale, would lose the grinding of 26½ quarters in addition, their loss would not then be worth minding.

That the loss of 33 quarters per week cannot be far from the truth, will appear by examining such collateral circumstances as have occurred.

According to the testimony of Messrs. BERNER and ROGERS, and also of JAMES FRENCH, who assisted them in examining the gates in question, by desire of the Trustees, (which they did the 24th of March, 1781) the whole value of the several openings, according to their estimation, and the water discharged thereby, compared with the quantity requisite to grind a given quantity of corn, (as deduced from an experiment made by myself upon this mill) could not amount to more than one quarter per day; but as the gates were doubtless then as carefully shut-to as the circumstances of their disrepair would admit of, which could not in general be the case when handled by bargemen, nor would they, from the same circumstances of disrepair, always shut alike, I look upon this experiment as made in their extreme degree of tightness.

Again, it has been fully ascertained and agreed, that during this state of disrepair of the gates, that the lock would sometimes be 15 minutes in filling, and that it was frequently necessary to draw the head-gates open by the tracking horse, sometimes being done by simply drawing them open, and sometimes by the use of a block; and that at such times, according to the opinion of WILLIAM BANNISTER, who preceded WILLIAM BASS as foreman at these mills, the water of the lock has not levelled by about 4 inches: he speaks of this, however, by estimation of the eye, not having ever actually measured it.

The tail-gates are also agreed to have been more leaky than the head-gates; had the tail-gates therefore been no more leaky than the head-gates, we may well suppose that 3 inches difference would have been sufficient to have brought as much water through the open flakers of the upper gates, as would have supplied their own leakage.

Now the quantity of water that would be vended by the two upper flakers upon a difference of 3 inches want of level, will be a given quantity, and will be equivalent

to the leakage of the upper gates at these times, and this checked with the quantity of water used for grinding a given quantity of corn, as before-mentioned, will amount to the grinding of $9\frac{1}{2}$ quarters per day: but as it was not necessary for the gates to have been always drawn open in this way, this appears to me to have been the extreme loss the other way, it is therefore fair to check the result obtained this way with what arises from the experiment of Messrs. BERNER and ROGERS, viz.

	Qrs. per day.
When the gates were so leaky as not to level within 3 inches, loss	$9\frac{1}{2}$
tight as per Messrs. BERNER and ROGERS, to lose but	1
	<hr/>
Sum	$10\frac{1}{2}$
	<hr/>
Half will be the mean	$5\frac{1}{4}$
	<hr/>

So that the average loss thus obtained will be $5\frac{1}{4}$ quarters per day, or $36\frac{3}{4}$ per week, which call 37.

And again, if we check the average result obtained from Mr. WYBURD's experiment, viz.

-	-	-	-	33 quarters per week,
Against the average result last collected	-	-	-	37
				<hr/>
			Sum	70
				<hr/>

Average of the averages 35, that is 7 loads, which at Mr. WYBURD's prices, stated at 7s. 3d. per load, is 2l. 10s. 9d. per week, and which, in my estimation, will be so near the matter as not materially to injure either party.

£.2 10s. 9d. per week, then, for 15 weeks is £.38 1s. 3d.

The idea of the millers, that they were losing as much water at the lock as would work a pair of stones, I must in this place observe I can have no reliance upon; had it passed through an orifice in one collected opening they might have had some comparative notion, but when cascaded in many different directions through the crevices of lock-gates the best judge of these matters would be liable to be greatly deceived, and from the magnitude of the appearance, judge it much more than it really was, and in this manner their idea of loss would be magnified from first to last.

Respecting, therefore, the charge of £.200 for two years preceding the 30th of October, 1780, no particular evidence was offered upon it, but the general one, that during all this period the lock-gates and flakers were greatly out of order; yet, since it appears that at three different times they were repaired, it is impossible to judge now what degree
of

of loss Mr. WYBURD might suffer during that period; but if his own comparative idea of the matter be taken, viz. that while he was suffering 5*l.* 10*s.* per week in the period specified between the 30th of October, 1780, to the 2d of April, 1781, he was suffering at the rate of 100*l.* per annum for the two preceding years, then the yearly allowance must be reduced in the same proportion as the weekly.

	£.	s.	d.
That is as 5 <i>l.</i> 10 <i>s.</i> is to 2 <i>l.</i> 10 <i>s.</i> 9 <i>d.</i> so is 200 <i>l.</i> to	92	5	5
Which, together with what was before ascertained,	38	1	3
Total for loss of water	130	6	8

With which I am convinced Mr. WYBURD will be fully recompensed for whatever loss he has in reality sustained.

I will only add that I would have it understood, that I have supported Mr. WYBURD's claim of reparation of injury to an individual as much as I can with justice to the Trustees as a public body; at the same time adverting, that as in the nature of the use thereof lock-gates cannot be made or kept perfectly tight for any length of time together, that a reasonable degree of leakage can be claimed by the Trustees as their right, by the same rule as they can take water for the lockage of the vessels, the mill estates upon this river being greatly benefited by the alteration of the mode of navigation from that of wears and flashes to that of cistern-locks.

J. SMEATON.

Ausborpe, November 12, 1782.

ST. IVE'S HARBOUR.

The REPORT of JOHN SMEATON, Engineer, concerning the practicability of making the harbour of *St. Ives* safe for ships in all winds.

THE bay of *St. Ives* lays about five leagues to the north east of *Cape Cornwall*, and is the first harbour of any consequence after the entry of the north channel; it lays nearly opposite to *Mount's Bay*, upon the entry of the *British* channel; and as there is a great scarcity of harbours on the north side of *Cornwall*, it becomes of consequence from its situation, not only to ships trading through the north channel, but to such ships as homeward bound from long voyages, by hazy weather, or other accidents which often happen, get into the north channel, when they intended to make the south.

For these purposes the bay of *St. Ives* is happily situated, and is sufficiently capacious, it being near four miles in width and above two miles in depth, having in general, and especially near the middle, full 10 fathoms at low water, with a clean bottom, being altogether a white sand, composed almost wholly of the small fragments of sea shells, so that having very little of what is gritty in its composition, and the particles being rounded by the motion of the sea, is so soft and smooth as not to hurt the cables of such vessels as anchor therein; and as underneath the sand there appears to be a blue clay (it being frequently brought up upon the flukes of the anchors) is very good holding ground, the anchors being never known to drag when drawing towards the land, as the ground that way gently rises, and in the contrary direction, as the wind blows from the landward, the sea will necessarily be smooth, or if driven out to sea can be of no ill consequence, as the passage is sufficiently open, with sea room enough.

At the north-west corner of the bay a bold rocky promontory, called the *Island*, is joined by a narrow neck to the main land, and projecting considerably forwards towards the east, forms a natural harbour on the north-west side of the bay, and defended from all winds except the north-easterly.

This interior bay forms the harbour of *St. Ives*, and is for the most part left dry at low spring tides; but on account of the fine soft sand before mentioned, that universally lines the bottom of the whole bay, affords a soft easy bed for ships to lay upon when left dry by the tides; and for such ships as have not occasion, cannot, or chuse not to come upon ground, here is an excellent road where ships of any burthen may ride, safe from

from all north-westerly, westerly, south-westerly, southerly, and south-easterly winds, in six and seven fathoms water, at low water spring tides, as appears by inspection of the draught of the harbour accompanying this report, where at fig. 6. vessels may ride in six fathoms, the point of the island called the lamp rock being open with the *Meran* point, and bearing N. by the compass, (as all the bearings herein after mentioned were taken) the *Meran* point distant scarce a quarter of a mile. At 7 there is in like manner seven fathoms, the lamp rock bearing N. by W. and at fig. 9. nine fathoms, the lamp rock bearing N. N. W. $\frac{1}{2}$ W. from all which places the church tower bears nearly the same, viz. W. $\frac{1}{2}$ N. and at the island of *Codrevy* E. by N. distant about $3\frac{1}{2}$ miles; but vessels are by no means confined to these places, the water growing regularly and uniformly deeper towards the middle, where the general depth is ten fathoms, but these are the marks which ships bring up by, who use the road, in order to be as much sheltered as possible.

From the sketch of the bay it appears, that the rocks mentioned to be without *Codrevy* island, together with *St. Agnes* and *Trevonse Point*, stretch north as far as N. E. by E. so that it appears that the road does not lie quite open except from the north to N. E. by E. these winds are not however dangerous on this coast, as they blow almost right out of the channel; yet it is desirable, for the sake of such vessels as come in here for shelter from the N. W. and westerly winds, or to prevent being driven back to *Milford Haven* * when outward bound, or towards the *Scilly Islands* when homeward bound, and caught with contrary winds; I say for whatever cause it may have been adviseable or necessary to come into this road, it is certainly very desirable that they should have a place of refuge in case they are caught with a hard gale of wind from N. E. while riding there; for to avoid this possibility, many ships are prevented from making use of the shelter the place naturally affords, and by that means meet with an unhappy fate, that might have been very safe in the road at *St. Ives*, of which there are many examples.

Conformable to this idea, the island beforementioned stretches away finely to the eastward, and the castle point aims very naturally towards the south, but does not stretch away far enough to the south to make a sufficient cover for ships laying aground within the same from the swell that is brought round the points when the wind is at N. E. or N. E. by N. for this purpose it seems requisite that the castle point should be lengthened by art, which, if done in a proper degree, will afford a shelter for above 60 sail of ships from all winds; and to this design occurs the following natural and considerable advantages.

* *Milford Haven* is 32 leagues to N. N. E. and though an excellent natural harbour when in it, yet its entrance is said to be with difficulty distinguished in lazy and dark weather.

1ft. There is a great flow of tide, the spring tides in general rise and fall from 20 to 24 feet; extraordinary great spring flow 26 feet from low water, the smallest at least 18, which least flow, leaving at least 3 feet of water upon the sand at low water at and within the greatest part of the space included between the castle and *Perolver Points*, it follows that there will be never less than 21 feet water at spring tides. A neap tide rises from 14 to 16 feet, and never less than 11, but as there will be at least 7 feet water left upon the sand at low water, it in like manner follows there will seldom be less than 20 feet water at high water round the pier head, and never less than 18.

2d. It is observed that on the west side of the bay, where the road of *St. Jee's* is situated, that for three hours flood from low water, the water runs into the bay in a direction N. by E. and after that, though the water continues rising three hours more, yet the set of the current changes to the contrary direction, so that the current sets out of the bay on this side nine hours, and into it only three; from hence arises this advantage, that if a vessel is too hard pressed in the road with wind at any point from N. to E. N. E. she can slip her cable, and sail within the pier whenever there is water, as well before as at or after high water; this set of the tide naturally tending to carry her thither, as also if outward bound she can go out at half flood, and save half her tide up channel.

In short, every circumstance seems to invite the completing this harbour for the safety of ships where nature has been so bountiful, nor do I see but one untoward circumstance to hinder its perfection, or annoy the same; and that arises from the great quantity of sand, of the species before mentioned, that is brought by the sea into *that* bay, which is formed by the island on the north side of the town: this sand being thrown up by spring tides becoming dry, and being of a light nature, is blown by the wind over the neck that joins the *Peninsula* to the main land into the harbour, and comes in such quantities as sometimes almost to bury the houses that stand on that part of the neck. There is no appearance however that this sand increases in the harbour, or stays there beyond a certain degree, which is somewhat variable according to the winds and tides; from hence it is washed into the bay, and from thence part will be carried out to sea again by the reflux of the tides, and part in time crossing the bay by circulation, it is blown and heaped up in immense quantities on the S. E. side of the bay, and in and about the mouth of the *Hale* river at the bottom of the bay, which is now barred till about half tide, and would entirely be choaked up thereby if not kept open by the great land floods. So that upon the whole there is no appearance of the harbour or road being any otherwise than they now are in many ages, supposing all the solids to continue as they now are; but it may be reasonably expected, on the erection of a pier from the castle point, that a part of the sand that is blown over the neck into the harbour, and from thence

now washed away again, may be intercepted by a pier, and there retained; and undoubtedly this in some degree must happen, yet with the precautions that I shall mention, and the provisions that I shall recommend, I am of opinion that the benefit to be expected from a pier ought not to be suspended on account of the inconvenience that may be apprehended from the sands.

In the first place, I would not recommend to carry out the pier further than is necessary to shelter such a number of ships as may probably require to lay in this harbour together; this I apprehend will be done with the length I propose, which is 60 fathoms.

2d. Had it not been on account of the sands, I should not only have proposed to carry the pier out further, but to have turned it more inward like the old pier; but this would in a greater degree have prevented the sands from washing out, nor can it be turned more outwards without laying the harbour too open, and exposing the pier to the direct shock of the seas.

It is probable that, notwithstanding these precautions, the sands will be lodged higher on the inside of the pier than on the outside, as may be seen in the old pier, but yet like those, these will never increase beyond a certain degree, and as there will scarcely ever be less than 20 feet at high water at the pier head, some increase may be admitted without losing the expected benefit: this is exemplified at *Scarborough*, where a considerable quantity of sand is lodged within the pier, yet the utility of the pier, which has been the work of many years, and many thousand pounds, cannot be denied.

To diminish the quantity of sand that now comes over the neck, in case it is found to annoy the harbour, I would propose to build a wall 25 or 30 feet high, supported by proper buttresses, in the direction A B C, by which means the current of sand will be directed so as to go over the low part of the island north of the battery on the *Castle Point*, and be carried into the sea at the little cove between the *Castle Point* and the battery upon *Meran Point*, and thereby totally avoid the harbour.

I would also recommend the planting of the sea rushes which are found to entangle the sand, and thereby in great measure prevent its blowing, so that it would be retained in the north bay, where it arises, and increase the breadth of the neck of land that joins the island to the main land.

These things being duly attended to, I am of opinion that the harbour may be kept in a great measure, if not altogether, clear of sand, and if any remains it, may be driven out

out to sea by constructing a reservoir to take in the tide water, in order to make a scower at low water.

With respect to the construction of the pier, that will in a great measure depend upon the ground whereon it is to be founded; the immediate bottom where the pier is proposed, is entirely sand, such as has been already described, and is to an unknown depth: I endeavoured to perforate the same by a proper instrument, but there being 3 feet water over the sand at low water, though spring tide when I was there, it was impracticable to make so satisfactory a trial as might have been done had the sand been left dry. However, this far appears, that at a little depth under the surface, it lays so close and compact that it was with difficulty that a sharp instrument could be got down 3 feet into the same. It is supposed that at some depth underneath there is a rock or clay, and it is probable that the rocks which compose the *Castle Point* may reach under the sand to a greater extent than they appear above the surface, but it seems very uncertain whether any rock can be met with whereon to found the pier, the whole, or any considerable part of the length. I therefore in the following estimate suppose that there cannot; and therefore propose to build the pier without any piles or wood-work, upon the principle which the French call *Pierre perdue*, or cast stones; that is to say, to drop a large quantity of rough stones in a proper direction and width, so as to form an artificial rock or base for the pier; these stones will by degrees sink into the sand, and being followed by others, these will rest upon the former, and so on till the first or lowest part becomes at rest; for the sand laying very close and compact underneath, will bear any weight when not affected by the action of the sea.

In this method a much greater quantity of stone will be needed than if the pier was built upon a regular base; but the whole of the base being of rough stones, the more irregular the better, of which great plenty may be got from the neighbouring rocks; as the whole will be done without timber work, and a large quantity of rough stones that would be needed to defend the timber work will be avoided, or rather compose a part of, and be included in the proposed scheme, it will upon the whole not only be much cheaper, but when well settled, more secure than any thing can be made upon a foundation of piles and timber upon the sand.

Upon these principles I propose to raise the pier to half tide, or even to the top, according as the materials are found to turn out; the principal use of this pier being a breakwater, or defence against the sea, the uprightness or lining of the inside for the purposes of a quay are less material; nor is it probable that it can be used for this purpose,

pose, as the spreading of the irregular stones at the bottom will prevent vessels from laying close home to the pier.

Having carefully viewed the several places from whence stones are likely to be got, and conferred with Mr. RICHARDSON, mason, who assisted me in this survey, upon the probable expence of winning, moving, and placing the same in order, I have accordingly formed an estimate of the probable expence, as follows.

ESTIMATE for building a Pier in the harbour of *St. Ives* of 60 fathoms in length, according to the plan and sketch accompanying the same.

The highest spring tides being 26 feet above the surface of the sand, the pier should be carried up solid at least 30 feet above the same, and supposing the whole to settle into the sand 6 feet, the whole height will be 36 feet, and admitting the sides to batter half the height of the pier on each side, and to be 24 feet broad at top, the base will be 60 feet, and the mean breadth 42 feet, or 14 yards; this multiplied by the height, 12 yards, produces an area or section of 168 yards in each yard running.

It is supposed that a pier built in the manner proposed with a parapet, regularly walled with *Abertaw* lime, will be done at the price of 6*s.* 6*d.* per cube yard; but as the quantity of settlement into the sand is not quite certain, with other contingencies sufficiently to allow for those, I estimate the whole at 7*s.* 6*d.* per cube yard, and this for 168 yards section, come to 63*l.* per yard running.

	£.	s.	d.
To carrying out the pier 120 yards, at 63 <i>l.</i>	7560	0	0
The parapet to be 9 feet high, 7 feet base, and 3 feet top, the mean thickness will be 5 feet, and contain 5 yards section, which, at 7 <i>s.</i> 6 <i>d.</i> per yard cubic, is 1 <i>l.</i> 17 <i>s.</i> 6 <i>d.</i> per yard running, and which for 120 yards is,	225	0	0
To extra work in finishing the pier head, cramps, iron, and lead,	200	0	0
	<hr/>		
	£. 7985	0	0

J. SMEATON.

Aylthorpe, October 25, 1766.

T O P C L I F F M I L L.

The REPORT of JOHN SMEATON, Engineer, upon the Practicability of removing *Topcliff* Mills, *Yorkshire*, to *Affenby* Stream, below *Topcliff* Bridge, consistent with the proposed navigation of the river *Swale*.

HAVING viewed the situation of *Affenby* stream, as also the present situation of *Topcliff* mills, I am of opinion as follows :

1st. That exclusive of the dam, which is totally ruined, the mill appears to be in bad repair, and built upon so bad a principle for doing business, as to be incapable of any considerable improvement, without intirely rebuilding.

2d. That the situation of *Affenby* stream is preferable to the present one, as there may be a better fall.

3d. That supposing the mill and dam to be entirely rebuilt, the only difference, in point of expence, in the present situation, or at *Affenby* stream, will be in the carriage of the old materials from the old situation to the new one, and in digging the cut at the new situation, and perhaps some additional charge about the mill stable and out parts of the mill-house, which, in its present situation, might possibly be saved.

4th. That the removal of the mill and dam will be equally if not more beneficial to the navigation at *Affenby* stream, than in its present situation, because it seems to me, that a dam raising the water 7 feet, or thereabouts, at *Affenby* stream, will pen the water up to the same level of the present mill, as it has ever been penned by the dam before it was destroyed ; and by building a dam at *Affenby* stream, the navigation dam below needs not be raised so high as it otherwise must be, in order to float the vessels over the shoal at *Affenby* stream in dry seasons.

Northallerton, 14th March, 1767.

J. SMEATON.

EYMOUTH HARBOUR.

The REPORT of JOHN SMEATON, Engineer, upon the Harbour of *Eymouth*.

THE harbour of *Eymouth* lays at the corner of a bay, at which ships can work in and out at all times of tide, or lay at an anchor secure from all winds, except the northerly or north-easterly. From this circumstance its situation seems very advantageous; but as the mouth of the river or harbour lies open to the northerly winds, ships cannot lay in safety therein without going up beyond the elbow of the present quay, where the water being shallower by several feet, and the breadth much contracted, the harbour is not only defective in point of capacity, but in safety also; for at a full sea the mouth being wide, the sea tumbles in with so much impetuosity, that great seas find their way round the elbow, and make the vessels even there lay not so quiet as is to be wished; in order therefore not only to enlarge the harbour, but very greatly to increase the safety of vessels laying therein, it is proposed to build a north pier to defend the harbour's mouth, and to this end nature has furnished a ledge of rocks, not only capable of making the most excellent of all foundations for such a pier, but in as advantageous a situation as could be wished, upon which a pier is proposed to be built according to the plans accompanying this report; for, according to the directions therein specified, the harbour will be defended from all such seas as annoy the bay, and the only point from whence the harbour could be affected by seas coming in through the mouth, are land-locked by the points of the bay; so that the harbour will, in its whole extent, be perfectly safe in all winds. It is also to be noted, that the same circumstances that concur to make the harbour safe in all winds, afford the vessels means for getting in and out at all winds*: and this proceeds from the entry into the harbour laying nearly at a right angle with the di-

* 1st. If the wind is right a-head to vessels coming into the bay, it will of course be smooth water, and there being room enough to turn, they can work in till they are near the bottom, and then sail with a fair wind right into the harbour. 2d. If a vessel comes into the bay before the wind with a great sea, she will also have the wind fair to sail into the harbour. 3d. If the wind is right a-head to her going into the harbour, she will have a fair wind into the bay with smooth water, so that after coming to an anchor, she can warp herself in. 4th. In like manner a vessel that wants to go out, if the wind blows right into the bay, she will have a fair wind out of the harbour, and having room in the bay, can work herself out to sea, unless it blows so hard as to bring on a great sea, and if so it would be undesirable to be out at sea upon a lee-shore. 5th. If the wind is right a-head to a vessel desiring to go out of the harbour, as the bay will be smooth, she can warp out, and being out, has a fair wind out of the bay. Lastly, a vessel going before the wind, out of or into the harbour, will have a fair wind out of or into the bay respectively; and a vessel going before the wind, out of or into the bay, will have a fair wind out of or into the harbour respectively.

rection

rection into and out of the bay ; it is also a great advantage that here is a good flow of tide, which at spring tides is said to be 20 feet, and there is at the lowest ebb several feet of water at low water between the proposed pier-heads, so that there will be seldom less at neap tides than 16 or 17 feet water in the harbour, which is capable of receiving vessels from 300 to 400 tons, according as they are more flat or more sharp built, and which afterwards can, upon a greater flow of tide, be got into a more advantageous birth.

Another advantage to the executing the proposed design, arises from a great quantity of rough rocks that lay at the north-westerly point of the bay, very proper for building the outsides of the body of the pier, the inside of which may be done with rough stones won or blasted from the neighbouring rocks to that upon which the pier is proposed to be built ; by this means the pier may be executed at a trifle of expence, in proportion to the extent and utility of the design ; for the rocks that are represented within the intended pier will be removed and made smooth, so as to procure an addition of harbour-room, at little or no charge, as they will be used within the pier : when this is done, there will be an addition of harbour-room in the space between the elbow before-mentioned and the pier-heads, capable of holding 30 ships of middle size, with sufficient passage, and which in time of war will be very useful on this coast, not only for the refuge of coasters from the enemy, but in bad weather for privateers and the smaller sized vessels acting offensively.

What relates to the method of the work itself, will be sufficiently explained by the plans and estimate ; I have only to remark, that I do not mean to fix the place of the pier to such precision, as not to be subject to be somewhat varied.

If it is found convenient, on account of fixing the base, to be a little more in, or a little more out, or the head somewhat nearer or further from the present head, than specified in the plan, I expect the surveyor to use his judgment therein.

Also I don't mean that the ground course of the stones forming the base of the pier should be exactly in a right line, or the bases cut to the same level, or answerable to any given delineation lengthways of the pier ; all I desire is, that a bed be cut for each stone declining towards the middle of the pier, as shewn in the plan, but they may be upon different levels, and a little more in or out, as best suits to get a firm footing for each particular stone, which stones must be suited in their sizes and thickness accordingly.

In regard to the repairs of the present pier and quay, where it is necessary to begin at the bottom, I advise to drive a row of piles 6 inches in thickness, and close together, edge

edge and edge, and the heads being connected by a string piece, to let the ground course of stones be notched upon them as was done at *Coldstream Bridge*. The rest of the quay will be defended by laying a tier of rough stones, sloped up against it at the foot, but not so as to be in the bilge-way of the ship.

This would be still more effectually done by driving a row of piles either close together, or at most but 9 inches distant from one another, and at about a yard distance from the foot of the pier, so as not to be in the way of the vessels, and to lay a slope of rubble stones against the foot of the pier, between the pile heads and the wall, as before described, observing always to slope the rubble down stream. This I think the best way of securing the present quay; but as it will be altogether defended from seaward by the proposed pier, and as the last proposed defence must be attended with some expence and trouble, being only to be done at short intervals of the tide, I advise to cut the matter of repair short by laying stones only, and take a trial of this till the north pier is built.

Aufbörpe, May 2, 1767.

J. SMEATON.

ESTIMATE for *Eymouth* Harbour. The expence of building a north pier.

The length of the outside, from the elbow and round the head into the flank within, is 240 feet, this multiplied by 22 feet mean height, produces 5280 feet super-

ficial, and this by 5 feet mean thickness, produces solid - - - 26400 cube feet.

The length within, from the elbow to the said flank, is 132 feet, which multiplied by 22 feet high, is 2904 feet superficial, and by 3 mean thickness, gives - 8712

Total solidity of the first stretch next the head, 35112

It is said, that such works as are represented in the inside can be brought from the rocks and laid in place at 6d. per foot, but as I understand this of the loose rocks already quarried, and as the quantity so produced may be short of the whole, and the quarrying is supposed to cost 2d. per foot extra, therefore, to make a sufficient allowance, I make 7d. per foot on the whole: the outside, the workmanship will be more rough, but the stuff being supposed larger, and worse to place and handle, I reckon on that also 7d. per foot,

To 35112 cube feet of stone in the outsides, at 7d.	-	-	-	-	£.	d.
					1024	

The whole circumference being 372 feet, this multiplied by $3\frac{1}{2}$ feet mean breadth of the basement course, produces 1302 feet superficial, this quantity of the rock will be required to be cut sloping towards the middle of the pier, and being tide-work, and the rock hard, I allow

To 1302 feet superficial of rock cutting for basement, at 8d.	-	-	-	-	43	8	0
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The length of the above being 173 feet, the mean width 24 feet, and mean height 22 feet, the whole content, in solid, will be - - - 91344

From which, deducting the outsides, - - - 35112

Remains for the solidity of the inside filling 56232
which is equal to 2083 cube yards.

Carried forwards 1067 10 0

	£.	s.	d.
Brought forwards,	1067	10	0
To 2083 cube yards (after deducting the outside blocks) of filling with rough stones*, to be placed by hand, and well packed, at 4s. per yard,	416	12	0
To 172 feet length of parapet, mean thickness 6 feet, and 9 feet high, produces 344 yards solid, which being well walled and filled with mortar, and built of free-stone rubble, I allow 7s. 6d. per cube yard,	129	0	0
To hammer-jointing and facing both the outsidcs, containing 3268 feet superficial, at 1d.	13	12	4
The cordon, being 172 feet long, and 2½ feet in breadth, and 1 foot thick, will contain solid	430		
The capping, being 174 feet long, 3 feet broad, and 1 foot thick, will contain	522		
Sum	952		
To 952 feet of <i>Leimerton</i> stone, worked, and laid in place, at 1s.	47	12	0
To flooring for the top of the pier, being 172 feet long, and, at an average, 6 feet broad, containing 1032 feet superficial of the same stone as the outside of the pier, at 8d.	34	8	0
To stone potts for mooring,	5	0	0
For 173 feet of pier next to and including the head,	1713	14	4
The length of the pier, from the elbow to <i>Gun/green Point</i> , being 181 feet, upon a mean height of 13 feet, the superficies will be 2353 feet on each side; and allowing the mean thickness on the outside 4 feet, and the inside 2½ feet, the mean thickness of both sides will be 6½ feet, and the whole solid formed thereby 15295 cube feet, at 8d.	446	2	1
To 724 feet of cutting the rock for the basement courses, which being left in the tide's way, I reckon at 6d.	18	2	0
The outside blocks being deducted from the solid contents, there remains for filling 1046 cube yards, which being more out of tide's way, I estimate at 3s.	156	18	0
To free-stone rubble walling in the parapet, being 8 feet mean base, 2½ mean top, and 7½ mean height, contains 264 cube yards, at 7s. 6d.	99	0	0
To hammer-jointing and facing both the outsidcs, containing 2896 feet superficial, at 1d.	12	1	4
To hewn work of <i>Leimerton</i> stone in the cordon and parapet, the cordon being 2½ feet broad, and the parapet the same, and 1 foot thick; this for 181 feet running contains 905 cube feet, at 1s.	45	5	0
To flooring the top of the pier between the parapet and ailer, the mean breadth being 5 feet, will contain 905 feet superficial, at 8d.	30	3	4
To rough stones to be laid in the angle of the pier, adjoining the land at <i>Gun/green Point</i> ,	3	0	0
For 181 feet of pier from the elbow to the point,	810	11	0
For 173 feet ditto next and including the head,	1713	14	4
Sum	2524	6	1
For contingent expences I generally allow 10 per cent. upon the whole,	252	8	7
	2776	14	8

N. B. As the rocks within the pier head will be got and made use of in filling the pier, I suppose this to be included in filling of the pier; but if fender piles should be thought necessary within the pier for vessels to rub against, the expence of those must be added.

* All stones in the filling are proposed to be put in whole, unless they arise of above two tons.

STONEHOUSE CREEK BRIDGE.

METHOD of construction of the Bridge over *Stonehouse Creek*, as designed by JOHN SMEATON, Engineer.

ON the *Stonehouse* side of the bridge there appears, from the borings and soundings made by Mr. JOHN MUDGE, to be a good hard clay bottom, which gradually declines from the quay towards the middle of the creek, but which at the further side of the channel at low water is 20 feet deep below the mark of low water spring tides; from thence for a space of 250 feet, that is till within about 80 feet of the opposite shore, the clay bottom can no more be felt with sounding rods of 26 feet long, which were the length of those made use of, so that for the aforefaid space of 250 feet the depth of the mud is not known; but from the manner in which it declines from each side, it is not unreasonable to suppose it to lay somewhat like the line dotted out in the plan, but whether this be so or not, the depth of the mud is assuredly so great, that to found the whole upon piles would be so very expensive, as to render the construction in that respect impracticable. It is therefore proposed by removing the water-way about 50 feet nearer the quay than it now is (that is, the middle of the arch to be about 100 feet distant from the quay) to take the advantage of the rise of the clay bottom, in order to found a couple of piers whereon the arch may solely depend, and to make the rest of the passage over the creek by forming a rampart with rubble stone, and quarry rubbish cast upon the surface of the mud, and heaped upon till the stones first cast, either ground themselves upon the clay bottom, or by consolidating the mud by mixing therewith, shall make an artificial foundation capable of sustaining the incumbent weight of materials above the surface of the mud; for this purpose, the piers of the arch being built square on the outsides next the ramparts, and quite upright, no settlement of the rampart will affect the piers, nor will any of the work of the ramparts be displaced in settling by encountering with any projection of the piers, nor will any damage ensue to any part of the work by such settlement, but what may be restored by addition at the top; and as there is plenty of rubble to be obtained on the side next *Plymouth Dock*, a considerable part of which would have been necessary to have been removed for the sake of forming a proper slope for the road up the hill, it is expected that this rampart may be formed at a moderate expence. The work of the rampart may be begun immediately; I will therefore first describe the manner in which I would propose to carry it on, subject nevertheless to such alterations as difference of circumstances arising from the process of the works shall indicate.

I would

I would propose then to begin at the end where the matter is to arise, bringing forwards the materials in wheelbarrows or carts as shall be found most convenient, merely to tumble them over the creek, observing to reserve the heaviest and best stones for the outside, the second best for the bottom, and the rubbish for the middle: I would advise to carry forward the work to its full height nearly as it advances, by which means the whole will obtain its full settlement in the least time. The breadth at top, and slopes therefrom, being as per section, the several widths at the surface of the mud, will be had by consulting the outermost ground lines of the plan; and as the work will begin from the shore, the additional width to begin with, in order to allow for settlement into the mud, will be found by experience as the work goes on.

The section of the rampart shewn in the design being adapted to the line *AB*, near the middle of the present channel, and supposing it to ground upon the clay bottom there, the beginning ought to be 72 feet wide, as therein shewn.

When the work is advanced some distance from the south-west side, and the mud grows deep, if it is found to swallow up a greater quantity of matter than is expected, it will be proper, by way of making a kind of bond or platform for the base, to stake down a double thickness of fascines or faggots upon the surface of the mud, and then proceed to throw the stones upon it, as is represented in the section; this will be not only a likely means of keeping the base from spreading as it goes down, but of producing an equilibrium sooner, in case it should not be found to go to the bottom where the mud is deep.

When the core of matter is found in some measure to come to rest, in order to get the proper breadth at top, it will be necessary to begin at the surface of the mud, and dispose the larger materials by hand, so as to form the slope or batter shewn in the section, which is nearly that of $\frac{1}{4}$ of the perpendicular above the surface of the mud, and is supposed to be the slope of an equilateral triangle below the same.

With respect to the founding of the pier, as the deeper will be near 10 feet below the low water spring tides, I apprehend it will be quite impracticable to get down to the clay without incasing; I therefore would propose to encompass a square area, capable of just containing the base of each pier, with a single row of dove-tailed piles, of 4 inches in thickness, to be driven a foot or 18 inches into the clay, more or less, as they are found to go harder or easier, and of a sufficient height to keep out the neap tides; that is, about 16 feet long, the heads of them to be regulated at top by strong pieces within, and supported by beams across, which may also be done in one or two tier below, as

shall be found necessary to support the proflure; which lower beams must be made moveable, and taken away as the work advances.

The mud below its surface will render the piles water-tight, and if not found so above, may easily be made tight, by throwing in some baskets of coal ashes, close to the piles on the outside, when the water lays against them.

As I do not expect the bottom to be level, it must be reduced thereto by forming one or more steps, as shall be found most convenient, observing to form the flat of the steps rather inclining towards the hill; and unless the matter happens to be so hard, that the piles cannot be drove therein full 18 inches, I would have the ground course next the water-way of the arch, and the returns thereof, laid at least 1 foot below the natural bed of clay, that the gulling of the water (which will soon carry away the soft matter down to the clay) may not easily get under the foundations of the piers.

When the first pier is raised sufficiently above low water mark, the piles may be drawn, and made use of in like manner for the other; and if there appears to be the least danger of the gulling of the bottom by the water, I would advise a part of the piles, of which the dam has been formed, to be cut to a proper length, and placed in the groove already formed, so as to be driven down, or cut off below the surface of low water spring tides; this to be done in the face of the piers, next the water-way, and the returns of the angles, but to the remaining parts of the piers it will be useless.

As this business will be tide-work, except at neap tides, it will be necessary to procure one or more good chain pumps, in order that the cavity may be expeditiously cleared of water; it will be advisable to have a couple of upright square pumps, of about 8 inches, (as they will stand in less room) to keep the water out after the bulk is evacuated, and for the standing of which an upright groove or recess may be formed in the back side of the piers; I advise two, that one may be in order, while the other is cleaning or repairing.

The arch, the facings, cordon, and capings, I would propose to be of *Portland* stone, the rustic part of the pillars of *Moor* stone, the body of the parapet over the arch of *Plymouth* marble, cut asiler; the spandrills of the arch of the same, either coursed or rough, as may be thought most proper, and the body of the piers below the rustic may be asiler'd, either with *Plymouth* marble or *Moor* stone, as may be thought proper on account of price; but if no great difference, I would advise *Moor* stone, as taking more kindly to the mortar, especially where constantly wet. The whole of the inside core I propose

propose to be of rubble from the neighbouring rocks. It will be adviseable to set the whole outside up to high water neap tides with *Watchet* or *Aberthaw* lime, and it would, as *Plymouth* lime is very tender in water, be also very adviseable that a quantity of the aforefaid lime was procured to mix with that of *Plymouth* for the inside work to high water spring tides: this is the more necessary, as *Plymouth* lime and marble do not seem disposed to form of themselves a very compact body, when constantly subject to the water.

Not having a plan of the quay at *Stonehouse* and housing adjacent, I have drawn the bridge straight; but as it may probably be found more suitable and convenient to make the rampart somewhat curved from the arch and termination upon the quay, I leave this to the determination of those concerned in the execution upon the place.

The above is, I think, the most material of such directions as at present occur, and which I hope will be found sufficient for beginning; if any thing is not sufficiently explained, shall be ready to do it by letter.

J. SMEATON.

London, June 15, 1767.

LINTON DAM AND SWALE NAVIGATION.

The REPORT of JOHN SMEATON, Engineer, upon sundry points relative to the *Linton* Dam and Swale Navigation, referred to his consideration by JOHN SMITH, Engineer for the said works; by order of the Commissioners.

The points were the following:

1. **W**HETHER any, and what allowance may be made for the declivity of the rivers *Ouse* and *Swale* in dry seasons, so as to depend on making a depth of water beyond the dead level of the height of the dam.

Answer. It is the practice of engineers in levelling to allow one inch per mile for the least sensible current, and this I apprehend may be safely allowed, but not more; I don't mean that there can be no current, under an inch in a mile; but that all methods of levelling are so precarious, where such minute differences are concerned, that it is as safe to make that allowance as to rely upon any other method to prove it, especially as it is easy in practice to remedy the defect by adding a rib of wood to the crown of the dam, in case its height should be found defective by a few inches.

- 2d. Whether the height of 11 feet above the surface of low water at *Linton* is necessary for the dam there above that surface, in order to make good the water to the mark near *Milby Staith*, which, according to his levelling, he makes to be 11 feet above the said low water surface at *Linton*.

Answer. The difference of 11 feet between the mark at *Milby*, and the low water at *Linton*, is precisely the same that I made it; which I particularly remember, having explained it to the committee in *London*, how I came to expect to raise the water to my proposed height at *Milby* by a 10 foot dam at *Linton*, observing that the distance being eight or nine miles, according to the common allowance of an inch per mile, that would make so many inches, and the remainder would be made by the thickness of the sheet of water going over the dam. I still remain of opinion, that, for the same reasons, if the dam at *Linton*, its crown is raised within one foot of the dead level of the proposed point at *Milby*, that the water will rise to its mark, at least so as it may be helped by a rib of wood as beforementioned, it being impossible to take levels with absolute certainty for

so great a distance. It is however to be remembered, when my plan was originally projected as above, the *Linton* dam was supposed one undertaking with the *Ure*, and being no more than a general design to shew the practicability, the utmost accuracy was not wanted; but as it may prevent any jealousy between the different parties interested if the *Linton* dam is raised within half-a foot of the dead level of the mark at *Milby*, I think it cannot fail to raise the surface of the water in its driest seasons to its mark at *Milby*.

3d. Whether the design prepared by Mr. SMITH for the dam at *Linton* is a proper one for the purpose.

Answer. The design exhibited is I apprehend upon the same principles as that at *Naburne*, but with improvements; and as that at *Naburne* has stood the test for several years, I cannot doubt but this will do the same if executed with the same care and judgment. It would seem to me to be more unexceptionable if the base was enlarged by 6 feet, and the top diminished by 6 feet, the lowest step to be raised 2 feet above low water, and the ascent from thence to the top to be divided into three equal steps instead of two. The greatest objection I have to this construction regards expence. It is greatly different respecting the body of the dam from what I proposed, and with the principles of my proposed construction; but I have acquainted Mr. SMITH, where the reputation of an artist is concerned in the success of his works, he certainly ought to proceed upon his own ideas, and not those of another. This is certain, had the navigation been opened before the *Linton* lock and dam was begun, which was the declared preliminary of my original estimation, in order to bring down stone from above for the construction thereof, that it would have been erected at a much less expence; as it now is, it may be a matter of computation into which my present occasions will not permit me to enter.

4th. Whether the design for *Linton* lock is properly adapted.

This lock is I apprehend upon the same construction as I have seen several by Mr. SMITH's father built several years ago, and which have stood and answered very well; the principal articles, in which I differ in grounds where I use wood bottoms, are the following.

1st. A bearing pile under each fill, ranging in the face of each wall, (but this is rendered less necessary by a sheet of piles, in Mr. SMITH's construction, under the face of each wall;) a ditto under each fill answering the middle of the chamber, and if the ground is more soft, a pile under the outward end of each fill.

2d. The

2d. The great fill for the lower gates, the pointings framed therewith under the thresholds, in order the more firmly to be bolted thereto.

3d. A double row of rabbeted piling at the lower gate fill to prevent the passage of the water in case the chamber-floor should become defective.

4th. The coffin stones made alternately long and short, broad and narrow, in order to prevent their walling joint and joint, as it seems to me must be the case if made of one dimension, as prescribed by Mr. SMITH.

5th. In good gravel bottoms, where stone is cheap, I have used it instead of wood, still keeping a row of piles under the face of the walls, with a ribband or string piece upon their head, two good rows of rabbeted piling under the lower gate fills, and a row of ditto at the tail of all.

The masonry of the lock in general seems well designed, and substantial ; but after all designs, good execution is a great matter.

KNOUCH BRIDGE MILL.

Proportions and directions for building the Mill at *Knouch Bridge*, by
JOHN SMEATON, Engineer.

THE two water-wheels for common use to be 11 feet 6 inches diameter, out and out, and 8 feet wide, the shrouds to be 9 inches above the soal, and to have 36 buckets, the rising boards to be $4\frac{1}{2}$ inches broad, and the breadth of the bucket-board such, that the point of one bucket may advance to the center line of the heel of the next bucket, and the cutting edge to be thrown to the outside.

The bucket-boards should not be of above 1 inch in thickness, and to strengthen them, I recommend a shroud in the middle; the construction I commonly use in wheels of this sort, is three pair of clasp arms with three rings, and then to put on the boarding of the soal parallel to the axis, so that the boards are nailed down upon the rings like a floor upon joists. The wheel case or race to be made to a true sweep, answerable to the wheel, to be continued from the lowest point under the axis for a quarter of a circle, ending at the height of the center, above which the breast wall to be continued upright to a proper height for supporting the trough, which, if thought proper, may be made of stone to the front of this breasting. The water in taking the wheel shoots backwards, so that the wheel turns the same way round, and the water is delivered at the tail, as an under-shot wheel; the water is drawn by two shuttles, answerable to the partition shroud in the middle of the wheel; but as it is impossible to describe the particular form of the trough, so far as relates to the drawing on of the water, without a draft, this shall be supplied in due time.

The water-wheel being 11 feet 6 inches diameter, there will remain 2 feet to complete the whole difference of 13 feet 6 inches; the whole height required for the surface of the water above the top of the wheel being only 1 foot 6 inches, there will remain 6 inches either to be added to the head of water, or to admit the bottom of the wheel to be laid 6 inches out of tail water, or to be expended partly one way and partly the other, according to the judgment of the artist.

Nos. for the two over-shot wheels.

The great cog wheel	-	-	-	64	} at $5\frac{1}{2}$ inches pitch.
The great lanthorn upon the upright axis	-	-	-	25	
The spur-wheel upon the upright axis	-	-	-	72	} at $3\frac{1}{4}$ inches pitch.
The 5 foot greystone lanthorn	-	-	-	19	
The 4 foot cullens or blue stone	-	-	-	15	
The 3 foot $10\frac{1}{2}$ French stones	-	-	-	14	
The 3 foot 7 inches cullens or blue stones	-	-	-	13	
The 5 feet greystone for shelling oats, its lanthorn	-	-	-	15	

N. B. The numbers above being put upon the spindles of each pair of stones respectively, and all being *supposed* to be placed round the spur-wheel, they would all go at their proper paces if driven together: therefore they may be suited together to either mill, as best suits the convenience of the miller.

For the flood-mill, it being proposed to remove one of the present water-wheels from the *Whiston* old mill, which are 14 feet 8 inches diameter in the ring, I propose to continue the same number of floats as at present, but to alter the mortices, so that the starts may hold the floats pointing to the center.

The float-boards to be 1 foot broad, and so as to form a circle of 17 feet 4 inches, the rest of the space to be filled up by oblique breast-boards like the wheels at *Kilnburst* forge; but shall shew the particular degree of obliquity, by a draft along with the trough for the over-shots.

The width of the wheel may continue the same as at present, viz. 5 feet 2 inches, but if it can conveniently be augmented to 6 feet, it will be the better.

The flood-wheel I propose to be a breast-wheel, and to be laid 7 feet below the full head, viz. the nose of the gate to be when shut 2 feet below head, and 5 feet fall; now as this will make the bottom of the flood-wheel 6 feet or $6\frac{1}{2}$ feet above the common tail-water, and as this wheel will do business with 3 feet or $3\frac{1}{2}$ feet tail-water, it follows, that it will do business when this river is from 9 to 10 feet higher than in its ordinary state.

The numbers proposed for this wheel as follows :

The great cog wheel	-	-	-	84 cogs	} at a 5 inch pitch.
The greatest lanthorn on its upright axis	-	-	-	25	
The spur-wheel on the upright axis	. .	-	-	72	} at a $3\frac{1}{4}$ inch pitch.
A pair of 5 feet grey stones	-	-	-	19	
A pair of 4 feet cullens	-	-	-	15	

N. B. If any other forts or sizes are thought proper, the numbers or the spindle lanthorn will answer, if made respectively the same as those for the over-shot wheels.

The over-shot mills above proposed will both be turned at once, with the same quantity of water wherewith one of the wheels of *Whiston* old mill was worked when I was there, and which was said to be about the whole quantity in dry seasons. This quantity will enable each of the over-shot mills to grind with great ease at the rate of a quarter of wheat per hour, that is 16 *Winchester* bushels per hour by the two wheels.

The breast-wheel will grind the same quantity as either of the over-shot wheels, but will require a double quantity of water, that is, it will require as much water to grind eight bushels per hour, as both the two over-shot wheels will require when grinding at the rate of eight bushels *each*; but as the two over-shot wheels will work at the rate abovementioned with the common summer's water, I apprehend it will seldom happen but there will be water to spare, and therefore it may be worth while to consider whether one of the over-shot wheels may not be omitted, and the breast-wheel used in short water times in its stead, and by that means the breast-wheel be brought to act in a double capacity, as a short water wheel as well as a flood wheel.

The over-shot wheels will work with 3 or 4 feet tail water, at which time there will be necessarily such plenty, that it will be very immaterial whether the breast-wheel takes more or less.

London, 15th June, 1767.

J. SMEATON.

P. S. If the staves of the great lanthorns are made of cast iron, as will be advisable, they may be made of a flattish or oval figure, and thinner than if made of wood, so as to give room for a stronger cog.

The following sketch respecting the situation will, I hope, make the whole clear.

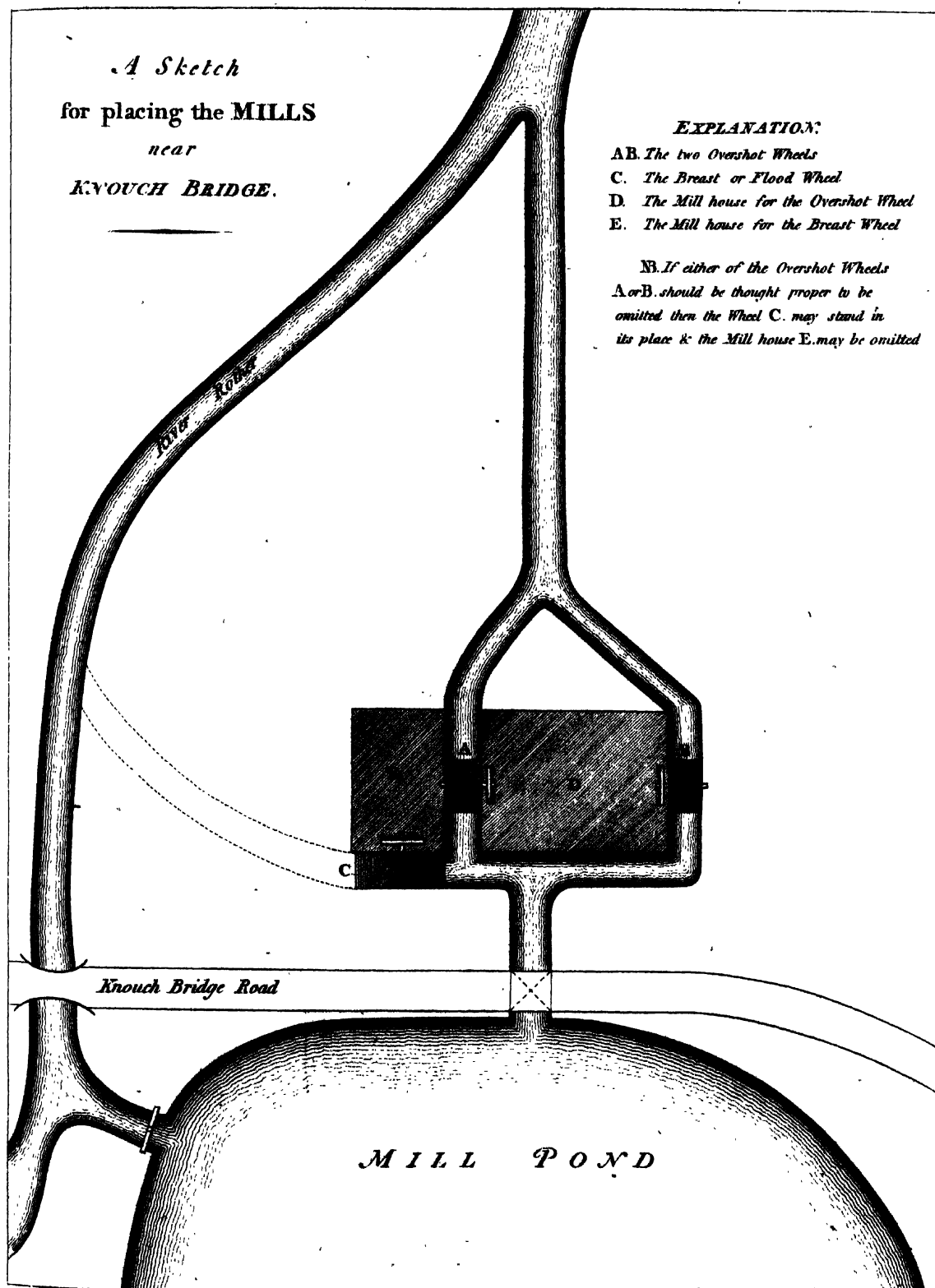


A Sketch
for placing the MILLS
near
KNOUCH BRIDGE.

EXPLANATION:

- AB. The two Overshot Wheels
- C. The Breast or Flood Wheel
- D. The Mill house for the Overshot Wheel
- E. The Mill house for the Breast Wheel

*NB. If either of the Overshot Wheels
A or B should be thought proper to be
omitted then the Wheel C. may stand in
its place & the Mill house E. may be omitted*



RIVER COLN.

PLAN for ascertaining the proportional quantities of water flowing down the high stream and *Iver* stream, being two divisions of the river *Coln* below *Uxbridge*, from whence also may be determined the quantity of water discharged at each place per hour.

THE sketch annexed is solely explanatory to save many words in description, and is therefore supposed not to be drawn from a scale.

The point A shews that branch of the river which comes from under the westernmost bridge of *Uxbridge*; this is not the whole of the river *Coln*, a considerable stream being diverted therefrom, called the *Cowley* stream, which crosses the great western road nearer the body of the town.

Below the point A the branch in question divides, one part turning the water-engine or colour-mill, and seems to have been an artificial cut, but the greater part of the water goes down the old river: those streams unite at B, and are again divided at C into two streams, called the high stream and *Iver* stream, the former being much the largest; from the point of division C the water runs with a gentle current to the bridge D, where, meeting the ford where the road crosses, and being somewhat pent up, it runs more rapid from thence to E, where this branch subdivides, but afterwards unite and join with the stream beforementioned.

From the point C the *Iver* branch runs with a very languid current till it meets the island F, after which it runs more briskly, as also at the bridge and ford at G it runs again languid till it gets into the inclosures, and then more briskly through the inclosures till it gets to the second bridge at H, where there is a further obstruction and fall, and from thence it runs to *Iver* mill.

Now, if a water-gage is erected upon the high stream, and another on the *Iver* stream at any place so far below the point of separation at C, that the water running from C to D, and from C to G, shall not be interrupted in its natural course, then those water-gages will respectively shew the proportion of the two streams, and afford a means of computing their real quantities, independent of any enquiries or evidence to be collected from the millers, and which may be executed in the following manner: Upon the branch of the high stream E L, and near the point L, let a water-gage be erected of

N. B. The water-course I R seems intended to discharge the overplus water in times of floods from the *Iver* stream into the high stream, the mouth of the passage at I being stopped up with piles.

30 feet in width, the fill whereof to lay even with the common surface of the water in dry times, to be terminated by two upright posts, and if need be, one in the middle, so to divide the same into two passages of 15 feet each, the whole to be made close and tight underneath the fill and on each side the posts, so that no water may pass during the use thereof but through the 30 feet passage over the fill, and consequently will fall over the same like a tumbling-bay. While this is erecting, the water may be turned through the passage E M, which will go to the mills as at present, but when compleated, the water, being stopped from going through E M, will wholly be obliged to pass the water-gage at L, and will raise the water there so little as not to affect the run of the water from C to D. Now, as the *Iver* stream runs more languid than the high stream, it will be necessary to go somewhat lower down, suppose to the bridge H, a little above which at N let a similar gage be erected, but with this difference, that as the *Iver* stream is not supposed to be above half the currency of the high stream, a gage of 15 feet will equally carry the water. As this width will not occupy the whole river there, the gage may be erected on one side, while the water let down to the mills on the other side, and being compleated, the bye passage must be stopped up, and the whole of the water be obliged to pass the water-gage, as in the other.

Now, upon turning the water through the two gages, if the depth of the current water upon the fill is equal, then the quantity will be in proportion to the widths; that is, that the currency of the high stream is double the currency of the *Iver* stream; but as the depths at first trial will probably be found unequal, let as many boards be put into that gage (end-ways up) upon which the water runs *shallowest*, as by straightening the water-way will cause it to run of equal depths with the other, then will the proportional quantities be as the widths respectively, when so adjusted, and this will be shewn by inspection, according to the various states of the river in dry seasons, whether the mills are drawn or not, and the experiment may be continued (with a proper attendance) for a month, or such time as shall be thought necessary; and account being kept of the depth of the water at different times, answerable to given widths, will afford a means of computation of the real quantity in tons per hour; but the computation of the real quantities is more matter of curiosity than use in the present case, for as the proposition is to take away no more water from the confined stream at A, than is due to the *Iver* stream, in any one given state, therefore more especially in the lowest state, it will follow, that if the whole river at A was afterwards parted by a gage, similar to those in the experiments, whereof that representing the *Iver* gage is conveyed to London, and the other to be conveyed down the high stream, after the *Iver* stream is stopped up by a dam, then will the high stream remain with its present quantity of water as heretofore, nor will it be surcharged in time of floods for want of passage down the *Iver* branch; because, whenever the river at C rises so high, as to afford more water than the

the mills can use, the stop or dam upon the *Iver* being made in the form of a tumbling-bay, the surcharge will be conveyed down the *Iver*, and for several months in the year will be a considerable running stream.

It will be necessary also to put a small gauge upon the little brook that falls into the *Iver* at the bridge C, which, when reduced to the same depth, must be deducted from the width of the gauge at N, and the width so reduced, in comparison with the gauge at L, will give the true proportion of the separation of the waters at C, and of the proposed separation at A. Again, as a quantity of water is proposed to flow down the *Iver* stream, in order to supply the neighbouring meadows, villages, and the town of *Colnbrook* with water, whatever the aforesaid little brook shall exceed or fall short of what shall be thought proper for that purpose, a due allowance can be made in the width of the gauge proposed to be erected at A.

It may be objected, that when the water due to the *Iver* stream is deducted from the river at A, that then the engine or colour-mill will lose a proportionable quantity of water ; but as the water flowing down the main stream is not employed in working any mill before this reunion, if, in dry seasons, the main river is straightened, in the same proportion by a flood-gate to be erected at O, and to be drawn up in times of floods, then will the engine or colour-mill be in all respects in the same condition it now is

It may also be observed, that the obliging the river to pass the water-gauges at A, may, in floody seasons, pen the water upon the tail of the mills just above the bridge of *Uxbridge* ; but as this *partition* will only be of use in dry seasons, it is proposed that there shall be a set of flood gates, that being drawn up, shall leave the river as capacious as it is at present, and, consequently, the mills in the same condition ; it is also proposed, that the water-gauge at A shall not be erected so as in dry seasons to pen up the water above the bridge of *Uxbridge* higher than it now is, so that the mills above the same shall not, in any season, be affected by the proposed undertaking. It is supposed, that this method of the partition of the water is (if possible) more unexceptionable than that of taking a given quantity out of the river or colour-mill head near A, as formerly proposed ; but that if this method be thought more eligible, as the gauges above-mentioned will afford a just method of computing the real quantity of water discharged by the *Iver* stream, a quantity may be taken by the method already exhibited, which shall

never exceed the just proportion in the driest seasons, and in all others rather fall short than exceed it, and still the surplufage, when too much for the mills and grounds, be discharged by the *Iver* stream in the same proportion as heretofore.

Aufiborpe, July 8, 1767.

J. SMEATON.

PORT GLASGOW PUMP.

DESCRIPTION of a Pump for the dock at port *Glasgow*.

THE water left in the dock at a medium to be evacuated by pump-work, is taken the 22d day of August, 1767, was

Mean length	-	243 0	} Solid contents 21141 Cube feet = 627½ tons.
Mean breadth	-	36 0	
Mean depth	-	2 5	

This quantity to be raised in 4 hours to the mean height of 4 feet will require 6 men working at a time, and good *English* labourers, will continue at the same rate for the whole time; but as the labourers to be employed will probably be such as can be promiscuously picked up, it will be proper to have two sets to relieve each other.

The distance of the chains from the axis of the lever to be $\frac{1}{2}$ of the length of the lever; it would be most convenient to have the center of the chains 2 feet from the center of the lever, but should not be less than 1 foot 6 inches.

The diameter of the working barrels to be 17 inches; and it would be well to have them lined with cylinders of hammered brass or copper, as iron will rust in salt water, and the bare wood will chamber too fast.

In the working of this pump it is to be noted, that when the height of the water without exceeds the height of delivery, that it will never rise higher in the mounting pipes above the chamber than just to force its way outwards, so that the water will never be raised to any height that is unnecessary, and with a proportional addition of force will throw out the water at all times of tide.

The 2 barrels A B are connected together by a square box or trunk C D, into which are 2 square passages through the working barrels E F, about 8 inches high by 10 or 12 inches wide; in the foreside of the box is an hole $10\frac{1}{2}$ diameter, so as to receive a pipe of $8\frac{1}{2}$ or thereabouts, which pipe is to be rammed tight, and to lay through the wall or bank into the open sea, the outward end of which may be guarded by a valve if thought necessary; but if the lower valves of the pump are tight, no water can revert into the dock; it will indeed rise to an equal height in the mounting pipes, but will there be at rest.

The buckets I would propose to be made in the same way as those for fire-engines, and the lower valves to be made double ; I propose them to be framed upon a cast-iron plate, closing up the bottom of the barrel, and which may be screwed to the barrel by 6 or 8 bed-screws, the nuts of which to be let sideways into the wood.

H H H H are blocks for the pumps to rest upon.

The iron rods and buckets will, I expect, be of weight sufficient to carry them down, but they should be steadied by passing through a plug or collar in the top of the mounting pipes.

The valves must be made light, particularly of the buckets, that they may meet with the less check in descending, and the whole leathured with pliable leather, which will be fully sufficient for a column of so small a perpendicular.

If the employment of 12 men for 4 hours be thought too much, this work may be done in 3 hours 20' by 2 ordinary horses, the pumps being contrived upon the same * principle, and 3 pumps to be worked by a triple crank, the proportions as follow :

Diameter of the working barrels	1 foot
Length of the stroke	3 feet
No.	
Lanthorn on the crank spindles	19
Face wheel for driving ditto	84
} cogs at $4\frac{1}{2}$ inches pitch	
Mean diameter of the horse-tract	21 feet

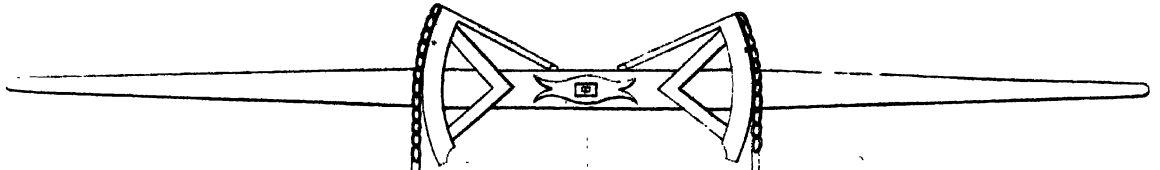
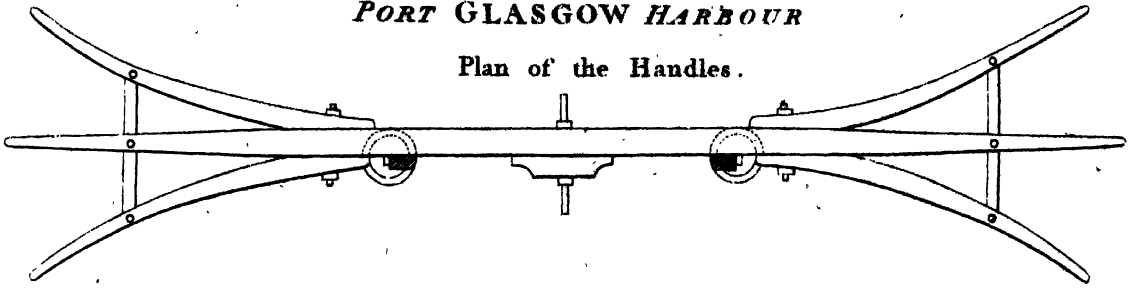
Ausborne, 4th September, 1767.

J. SMEATON.

* That is not to lift the water above four feet at low water, and no higher than to overcome the resistance from without, at all other times.

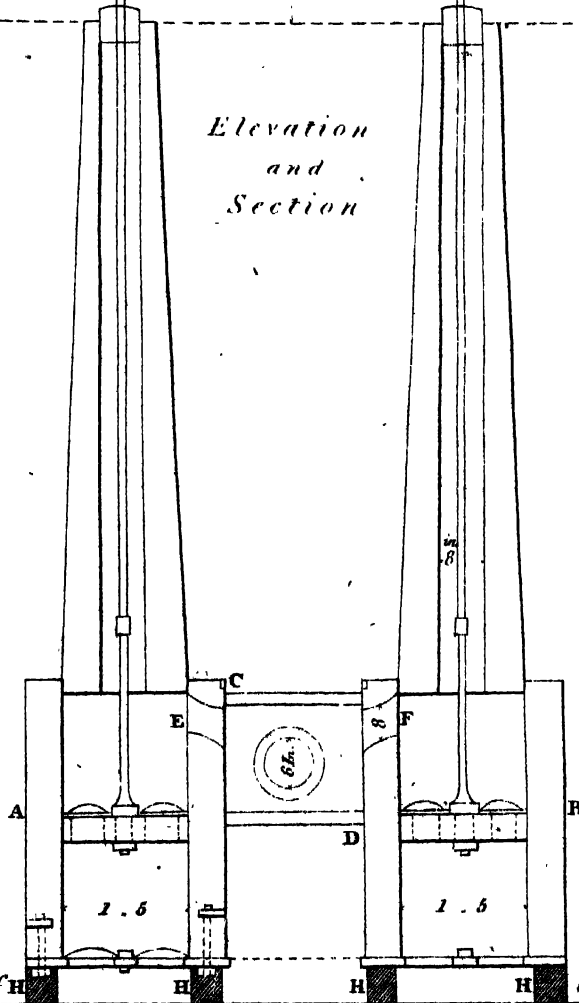
PORT GLASGOW HARBOUR

Plan of the Handles.



2. 10

Elevation
and
Section



RIVER TRENT.

The REPORT of JOHN SMEATON, Engineer, concerning the Water-Road proposed to be carried across the valley of the river *Trent* from *Muskharn* to *Newark*.

THE points relating to the road abovementioned, referred to my consideration by the trustees thereof, at a meeting on the 19th day of December ult. were as follow:

- 1st. The propriety of the choice of the ground for the new road.
- 2d. The proper height of the road in respect of the water-line at the extreme of high floods.
- 3d. The proper quantity of water-way for the necessary passage of the water across the said road in time of the said floods.
- 4th. The particular places where the arches ought to be situated, and the number and dimensions of the arches proper at each particular place.
- 5th. The best method of construction of the said arches, so that they may be done at as little expence as possible, consistent with their being effect al.
- 6th. The proper section of the road where it passes through the grounds to be ramparted.

These are the propositions as I understand them, being verbally delivered.

1st. I am of opinion, that the ground marked out in the plan for the track of the new road is very properly chosen, being in general over the highest grounds, and sufficiently straight; and I look upon it to be an advantage that the arches will be as much as possible together.

2d. I apprehend that, to prevent damage to the road by its being overtopped, it will be advisable to make up its crown or summit to the height of 1 foot above the respective water-line at the extremes of floods; and the top of the road being convex about
6 inches,

6 inches, the sides of the road will then be about six inches above the said water-line, which height above the water-line will also be necessary on account of the settlement, even after finished, though consolidated in the best manner practicable while making.

In order to ascertain the respective heights of the road above the surface of the ground, a point at *Newark Bridge* was shewn me by Mr. HANDLEY, as that to which the highest floods were never known to rise, and which has not been touched these 30 years: from this point I took a level to a mark at *Muskhams Bridge*, shewn me by a person of *Muskhams*, as the point to which the said floods arose; from whence it appears that at a medium of two operations the flood-mark is lower at *Muskhams Bridge* than that at *Newark Bridge* by 17 inches; and though this medium differed 5 inches from the extremes (which difference of the two operations was the result of carrying the level 3 miles) yet it is probable it is very near the truth, as it differs but $1\frac{1}{2}$ inch from the level put down upon Mr. WILKINSON's plan in the middle of Lord MIDDLETON's lands, between No. 18 and 19, near *Muskhams Bridge*. The level of the high water mark upon the bridge itself was shewn me by a different person from him that shewed the high water mark to Mr. WILKINSON, therefore they probably are not the same; and I have reason to believe, that from that part of the bridge having been repaired since the great flood abovementioned, the point shewn me was at least 6 inches lower than the real height of the great flood referred to, so that the fall of the water's surface from *Newark* to *Muskhams Bridge* will be reduced to about 11 inches. I have driven picquets near the course of the proposed road, between the two bridges, to the places of which the numbers in red refer upon the plan; and having given, by a section of the tract of ground, the respective depressions of the said picquet heads below the water-line, upon a supposition of 11 inches fall of the water's surface between the two bridges, this will be a sufficient guide for the laying out and forming the road.

3d. The proper quantity of water-way cannot, as it seems to me, be determined upon any fixed principles, because it is very difficult, if not impossible, to determine exactly what proportion of water in great floods runs over the surface to that which runs through the two bridges; all that can be done, therefore, is to make the best estimation we can, rather erring by allowing *too much*.

It happened somewhat luckily on this head, that I passed between the two bridges in a boat at the very highest of the great flood which happened on the melting of the snow in February, 1766. I then remarked the height of the flood by a fixed mark, to which on this occasion I referred, and found that the surface of the water was then within $6\frac{1}{2}$ inches of the height that was now shewn me at *Muskhams Bridge* as the highest of all. I
also

also then took particular notice of the quantity of water flowing through the rails, gates, and void spaces in the hedges, and considering the great depth of the river in its own channel, and the great obstructions the flood waters met with in passing the hedges from wreck, &c. deposited therein, I cannot in my own mind suppose that the whole water passing over the surface of the lands could equal that which passed through *Muskham Bridge* alone; but, that we may err on the safe side, let us consider the capacity of both bridges. Having, on the present occasion, taken dimensions of the water-ways of both bridges, and compared them with the length of the arching that will be equivalent thereto, upon a supposition that the flood arches upon an extreme flood carry a depth of water upon their floors of 6 feet at a medium, I find them as follow:

	Yards running.
<i>Muskham Bridge</i> equal to flood bridging	154
<i>Newark</i> ditto	99
	<hr/>
Equivalent of both bridges in flood bridging	253
	<hr/>

In order to check the above, I took an estimatory account of the whole openings in the line of the hedge on one side the present road through which all the flood waters must pass that run over the surface of the lands, and make them amount to an equivalent of flood bridging of 333 yards.

Now the mean of the two determinations will be 293 yards, but for a round number let us say 300 yards, which is near $\frac{1}{3}$ more than the sum of the capacities of both bridges: now this quantity, properly disposed of, will, in my opinion, be amply sufficient for discharging the flood waters, without the least danger or detriment of either the lands above the road, or to the road itself; and if the expence should make it needful, I am of opinion that the quantity above mentioned may be retrenched.

4th. The next article is the proper disposition of the arching above mentioned; and on viewing the face and levels of the country, it appears that the places where the flood-bridges now are, viz. at *Crankley*, and the three bridges, are the principal outlets for the flood waters. This experience has taught our forefathers, as is manifested by their placing bridges in those places; it follows therefore that those natural hollows, which lead the waters to those points, will be the properest places for the new flood-bridges, at the same time disposing of some arches or tunnels quite through the whole, to prevent any water remaining pent between the hedges in any particular place.

The arches I would recommend are of 12 feet wide, and 6 feet from the floor to the springer; they may be nearly all alike, except that in such places as will admit thereof, the floors may be laid lower, and the piers raised higher above the foundation than before specified, in order that one with another they may be of 6 feet depth of water; for lesser communications, I would propose tunnels of 5 feet width, covered by semicircular arches, the depth from the crown to the floor to be 6 feet, and the crown of the arch on the under side to be 2 feet 6 inches under the crown or summit of the road. According to these dimensions, three of these tunnels will be equivalent to one of the arches.

The places of the arches and tunnels as follows:

	Arches.	Tunnels.	Extent in clear water-way.	
			Yards.	Feet.
In the low ground between the north end of <i>Newark Bridge</i> , and the higher grounds opposite the warehouse, - - -	9	0	36	0
In Mr. RIDGELL's close, - - - -	2	2	2	2
In THOMAS WOOD's ditto, - - - -	0	1	1	1
In JAMES HANKER's, - - - -	0	2	2	2
Cross the valley at the three bridges - - -	24	0	96	0
The further hollow in Mr. STEVENSON's close, where the piquet, No. 8, is placed, - - - -	0	3	4	0
In the drivers, where the piquet, No. 12, is placed, - - -	0	1	1	1
In the great hollow from the drivers to <i>Langdale</i> , crossing the water-course that leads to <i>Crankley Bridge</i> , - - -	24	0	96	0
In the low flade in the rector of <i>Kelham's</i> ground at No. 16, -	6	0	24	0
In the crossing of the old road, - - - -	3	0	12	0
In Lord MIDDLETON's land, near the south end of <i>Muskeham Bridge</i> , -	3	0	12	0
Between <i>Muskeham Bridge</i> and the high land at the north end thereof, -	3	0	12	0
	<hr/> 72	<hr/> 9	<hr/> 300	<hr/> 0

The above is the best disposition I can form for the placing of the water-ways from my own observations and the information I have had; but as the going away of the present snow may probably furnish a good opportunity of making observations upon the currency, it would not be improper to appoint a discreet person for that purpose. I am opinion, however, that if the arches in those two places, which are laid out for 24 arches each, were reduced to 21, the water-way would be very ample.

5th. With respect to the construction of the arches, having explained myself by a design, I have the less to say thereon: it is necessary however to observe, that respecting the

the foundations, I have supposed it a firm gravel or clay, at the depth to which it will be necessary to excavate ; but where it proves a soft clay, loose gravel, or sand, or still softer matter, it will be necessary to pile under the piers. In ordinary cases, piles from 5 to 8 feet long, and from 6 to 8 inches diameter, driven about 2 or $2\frac{1}{2}$ feet distance, middle and middle, will suffice ; but as nothing can be ascertained on this head, without trial of the individual spot of ground in question, and as the firmness of the ground will frequently vary one pier from its next neighbour, the quantity and size must be increased or diminished, at the discretion of the surveyor.

Where piles are not used, I propose the first course of bricks to be set edgeways upwards, the length of the bricks crossing the base of the pier, the whole to be driven down with a paviour's rammer in the manner of a pavement, and after that the interstices run full of grout or putty, or if wet, to be filled with quick lime. If piles are used, bricks or half bricks to be drove down in the same manner in the interstices between the pile heads, and then to begin the regular courses upon the paving and pile heads promiscuously, being grouted as before. It is hardly necessary to say, that where a good foundation can be come at by going deeper, at a less expence than piling, it will be proper to do it.

As the arches are proposed to be but 12 feet wide, in order to avoid an unnecessary quantity of brick work, I have supposed the shafts of the piers to be but $2\frac{1}{2}$ bricks thick, which, if built firm inside and out, will be very sufficient to carry the loads in such short spans ; the arches themselves I have supposed to be no more than one brick thick, which I am also satisfied, if well done with good materials, will be quite sufficient : yet, as the supporting parts in the elevation have somewhat of a light appearance, if to satisfy the eye the trustees think it proper, half a brick may be added to the piers, and also half a brick to the arches within, which will make but little alteration in the design.

To save expence, I have supposed the whole to be of brick, the cap stones for the terminating pillars of the parapet excepted, which are necessary to be of stone, on account of weight to keep on the brick capping ; but if the expence can be admitted, it would give the whole a more substantial appearance to those who travel the road, to have the whole capping of stone. I suppose that the shoulder angles and springers of the piers, together with the capings, if of brick, to be made of their proper figure in moulds for that purpose.

To make all the piers thick enough to support all the adjacent arches *single*, without the counterbalance from the neighbouring arches, would bury a large quantity of ma-

terials ; I have therefore adopted the thought of my ingenious friend Mr. MITCHELL, in making every third pier or every fifth strong enough for this purpose, that in case of accident the damage may not be progressive.

6th. In regard to the proper section of the road, it appears from the general section, that the flat ground from the point No. 4, to the three bridges, is the deepest flooded of any part that will be done by ramparting, and that the depth at a medium below the water's surface is 4 feet, the mean height therefore of the crown of the road will be 5 feet ; and for this height a section is drawn, shewing the excavations necessary on each side, in order to furnish matter to form it when consolidated ; but if the bottoms of the canals on each side do not afford gravel for a cover, then the excavations may be of less width on account of this part of the matter being brought from a distant place ; but whatever be the height of the rampart, the same section will regulate it, by supposing the top of the road and angle of the slopes on each side to remain the same, and therefore the width only of the base to be variable, according to the quantity of matter required.

I suppose that in a few years the ditches will silt and grafs over so as to become pasture land, but as it will not only be unavoidable, but in some measure useful for the water, in time of great floods, to have a current along those ditches, it will be proper, as early as possible, to sow them with hay seeds, to prevent their sides from slipping, or from being galled by the current while they are new.

In order to prevent the surge, which in time of great floods will be raised by the action of the wind from washing down the sides of the rampart before it can get firmly swarthed over, it will be necessary to set the slopes of the ramparts with fods, in the manner shewn in the section ; and if the slope of the ditch next the rampart, as well as the opposite side where it faces the arches, was foddled also, it would be still better.

I have drawn the section of the road so as to afford a breadth of 30 feet for the tread of the wheel, which I apprehend will be quite sufficient, especially where the rampart is raised high, as well as in the bridging ; but in the high grounds, where the road is to be but little raised, it will not be necessary to be confined to this width.

Ausborne, January 11, 1768.

J. SMEATON.

GLASGOW BRIDGE.

Copy of a REPORT delivered at *Glasgow* by Mr. SMEATON, in October, 1760, from a copy thereof received from Mr. MURDOCK in a letter, dated April 20, 1768.

“ Report concerning the situation of the intended new bridge over the river *Clyde* at *Glasgow*.”

HAVING carefully examined the river at seven different places, viz. 1st, opposite *Jamaica Street*; 2d, at the middle of the island, commonly called *Ducat Green*; 3d, in a line passing behind the *Gorbal* church; 4th, in a line agreeing with the street that runs before the *Gorbal* church; 5th, at the present bridge; 6th, at the slaughter-house, in a line with the new street; and 7th, at the *Green* of *Glasgow*, almost opposite to the gate leading from the bottom of the *Salt-Market*, of which a particular account is contained in the paper annexed, from whence it appears to me that the situation of the present bridge is not the most eligible, for the following reasons: 1st, On account of the greatness of the length which will increase the expence; 2d, by the street answering thereto on the *Gorbal* side being too narrow, and embarrassed for the main avenue to a bridge of 30 feet wide; that street being not above 22 feet at a medium, and in several places not 18 feet; 3d, because it would not be safe to build a new bridge in the same place, except conformable with the old foundations, which would subject the new bridge to great irregularities; for as the present bridge appears to be founded upon the surface of a crust of gravel, covering mud or sleet to an unknown depth, was the new foundation upon the interstices, and the old ones removed for the sake of giving a free passage to the water, as this crust is undoubtedly broke through in many places by piles, &c. it would be dangerous to remove them, lest, by giving advantage to the speats to gull away the ground from thence, a free passage is given to the mud to escape, and thereby to render the new pier liable to settlements. 4th, The disadvantage of wanting a bridge during the time of building a new one, or the charge of a temporary bridge balanced against the small value of the old materials, are too obvious to need insisting upon. 2d, The position agreeing with the front of the *Gorbal* church is not the most eligible on account of the great length between the top of the bank on each side, so that it would require the extent of the bridge to be greater than its present situation; and as the north end would abut upon the workhouse dyke, would be too near, and too confined, without an opportunity of forming any new street in any good direction from thence, nor is the

the avenue from the south abutment free from objections, being but 27 feet in the widest part, and not above 19 opposite the church wall, which would require to be removed, and some private property purchased; nor is the cross street leading to the turnpike less exceptionable.

3d. The position agreeing with a line passing behind the *Gorbals* church, will clear the south abutment of all incumbrances, and mend the north in regard to the practicability of making an opening into the green beyond the row of trees called the *Old Green*; but till that is done will be as much confined as the former, nor will this situation admit of any street in any good direction into the town, without passing through gardens and private properties; add to this, that here the bridge will be required the longest of all, the distance from the tops of the banks being upwards of 600 feet.

4th. To the position agreeing with *Jamaica Street*, are the following objections: the bottom is worst of all, and the water deepest, nor does the line of this street produced cut the stream at right angles, which is a disadvantage that ought always to be avoided if possible; but without insisting on any objection to this situation on account of its being too near, and too much confining and embarrassing the present wharf or landing-place, or on account of its being too far removed from the present bulk of inhabitants, the foundation is a matter of consequence, for though the mud or sleet that lies under the bed of gravel is much of the same consistence as above (if any thing more soft), and may be made capable by proper care and caution of bearing the superstruction of a bridge; yet as the upper crust is considerably thinner, and less compact than above, it is justly to be apprehended that when the channel comes to be contracted by the piers, the increase of velocity of the water, in time of speats, may take away the bed of gravel between the piers, and by laying the mud exposed to the action of the water, may produce fatal consequences upon the adjoining piers, and this cannot be prevented but by a considerable addition of expence in the original construction, in piling, setting, and framing the whole of the spaces between the piers.

5th. At the slaughter-house, in a line with the new street, the river is of a moderate width, the running sand below the gravel lies the closest I ever met with at that depth; yet as the upper stratum of gravel is but loose, and the under crust very thin, this foundation is not without suspicion on account of the speats, nor does the line of the new street make a right angle with the stream of the river; so that after pulling down several houses in order to open an avenue thereto, the direction of the bridge cannot properly stand in a continued line with the street; the avenue on the south side will also be embarrassed in passing the *Gorbals*, for after pulling down some houses to make an avenue

answerable

answerable to the cross street leading to the turnpike on *Paisley* road, that street itself is in many places not more than 16 or 17 feet wide.

6th. The foundation at the green at *Glasgow*, opposite the gate leading from the *Salt-Market*, is much the same as at the slaughter-house; the objection with respect to a passage through the *Gorbals* the same; the avenue from the bottom of the *Salt-Market* might be somewhat enlarged, by removing the garden wall, but the clear between the houses in the narrowest place is not more than $25\frac{1}{2}$ feet.

7th. It now remains that we examine the position at or near the middle of the *Ducat Green*; the width of the river between water and water is least of all, being at the boiler 345 feet, and from the top of the bank on the south side, to the top of the high ground on the island, 495 feet; from that point measuring across the *Green*, to the middle of the road down the avenue of trees, is 180 feet; from the top of the bank on the south side, to the *Paisley* road in a direct line through the arable ground, 600 feet, which, allowing the breadth of the road to be 40 feet, will scarcely amount to half an acre *Scots*: in this position the new bridge will be about 900 feet distant from the present bridge, unembarrassed at either end, and capable of joining a new street that might hereafter be made across the *Old Green*, which may be made in a right line upon an arable close, and join the *Troangate-Street* near to Mr. BUCHANAN's house, without interfering with any present buildings or gardens. The obliquity of the stream of the *Clyde* with the line will indeed occasion the position of the bridge not to be in the same line, but the obliquity will not be such as to occasion any material inconvenience with respect to the useful part. The foundation at this place, though not perfectly the best, is yet as good at bottom as any, and the bed of gravel as thick, and in general as compact as any, but the upper crust for about 8 or 9 inches not quite so hard as at the ford opposite the *Gorbal Church*, and at the present bridge, but much more compact than it is lower down; however, to remove all objections on account of the ground, I would propose to make the sum of the openings of the new bridge equal to the span of the river in that place; and consequently, as the velocity of the water in time of speats would not be increased, there is no reason for supposing that the said gravel that now sustains their efforts, will not continue so to do; and this may be done two ways, 1st, by digging away so much of the south side of the *Ducat Green* next the river as shall be equal to the sum of the solids of the bridge, and with the earth to fill up the back drain; 2d, by setting the abutments a little within the land on each side, and to procure a further addition of free passage by widening and deepening the back drain, over which I would throw a single arch.

The former way would be the more eligible, on account of the conveniency of passages to the bridge, the latter will in that respect be sufficient, and amply so whenever a new street is made; but I apprehend the latter would better answer the conveniencies of trade; for the widening this back drain to 40 feet, so as to admit of two vessels a-breast, will admit of a convenient wharf on both sides, and will have this further effect, that a great quantity of water coming down this back drain in time of speats, would cleanse the face of the present quay, which towards the upper end is almost choaked up, arising from the main stream being chiefly on the south side.

It therefore seems to me that this situation of a new bridge will, upon the whole, be attended with the least inconveniences, be executed at the least expence, suit the conveniences of the present inhabitants, and favour any improvements that may be made further.

Glasgow, October 20, 1760.

(Signed)

J. SMEATON.

Measures, Soundings, and Observations made upon the river *Clyde*, relative to the choice of a proper place for the intended new bridge at *Glasgow*, made the 13th, 15th, 16th, and 17th of October, 1760, by JOHN SMEATON.

	Span of the Slope to the top of the river water and water.		Bray. On the South. On the North.		Sum.	Depth.	Qualities of the soil in the middle of the river to 10 feet deep.
	Feet.	Feet.	Feet.	Feet.			
1st. Opposite <i>Jamaica Street</i> , - -	384	54	50		488	3 6	3 feet of loose channel, below mud or fleech.
2d. At the upper boiler on the island,	345	100	50		495	2 6	5 feet of good channel, below ditto.
3d. Behind the <i>Gorbals</i> church, - -	348	150	150		648	1 6	4 feet of good channel, below ditto.
4th. Before the <i>Gorbals</i> church, - -	389	68	133		590	1 6	1 foot of hard channel, 3 feet looser ditto, and mud below.
5th. At the present bridge, - -	536	21½	28½		586	3 0	1 foot very hard channel, and below ditto.
6th. At the slaughter-house, - -	360					2 0	3 feet loose channel, 1 foot hard ditto, below a running sand.
7th. At the <i>Green</i> of <i>Glasgow</i> , - -	370					2 0	Ditto.

N. B. The general height of the bank on the south side is 13 feet above low water; the height on the north side about 9 feet; there being then about 2 feet water upon the hirk.

WHITEHAVEN HARBOUR.

The REPORT of JOHN SMEATON, Engineer, upon a View of the Harbour of *Whitehaven*.

HAVING carefully viewed the harbour of *Whitehaven* upon the 7th and 8th of April, 1768, I am of opinion as follows :

That in case the expence and length of time attending such a work would permit its execution, that the noblest and best scheme would be to carry out a north pier, and to lengthen the new pier, till the heads of the two piers should be within a competent distance (suppose 200 feet) of each other ; but as I apprehend it would be many years before much relief could be procured to the trade by so extensive a work, the most ready way of enlarging the harbour would be by extending the old pier by some additional works, the particulars of which it will require leisure to judge of ; but I am clearly of opinion, that if during the coming summer the old pier can be lengthened 30 yards, and turned a little more outward than the present direction, it will perfectly agree with every just idea of what is to follow, and that the prolongation aforesaid should be the first work done ; and if during this time a correct plan of the harbour, piers, and appurtenances, together with the coast as far as *Rednefs Point*, is prepared to be laid before me, I shall then be in a condition to judge more accurately of what is to follow.

Cockermouth, 8th April, 1768.

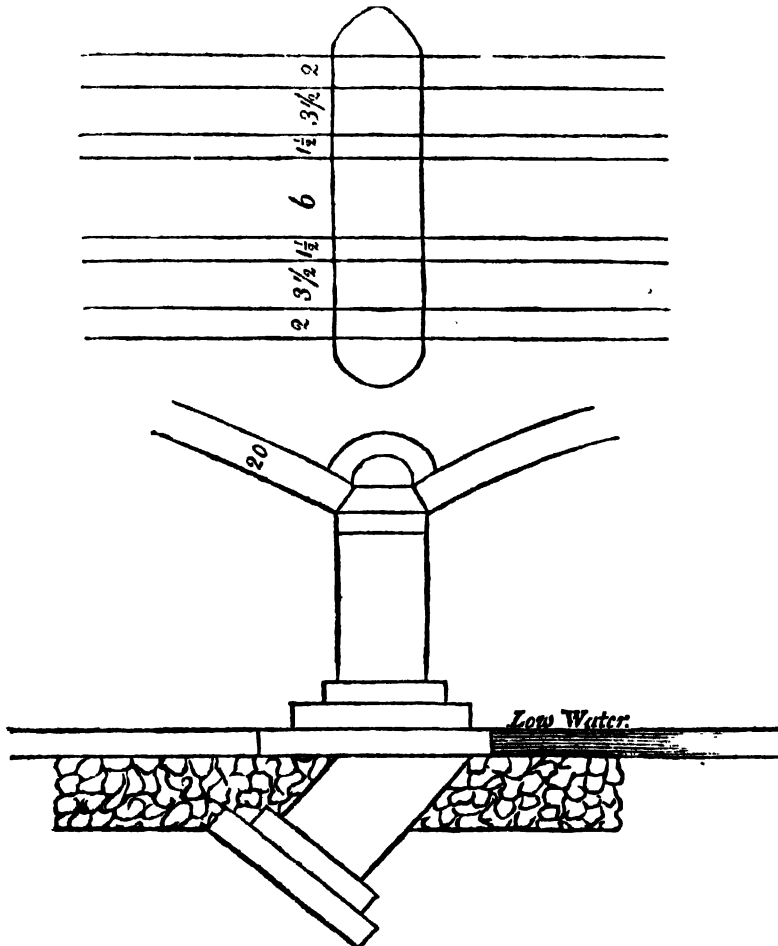
DUMBARTON BRIDGE.

The REPORT of JOHN SMEATON, Engineer, upon the rebuilding the sunken pier of *Dumbarton Bridge*.

HAVING viewed and examined the sunken pier of the bridge of *Dumbarton*, and the nature of the ground upon which it stands, and finding that it is a soft mud to a depth unknown, it being tried to the depth of 46 feet below low water mark, I do not know of any certain method of founding in such a situation; but, considering the very great difficulty and expence that will probably attend the taking up the present work to the bottom, being about 17 feet below low water mark, and the great uncertainty of better success, if that could be done, I am of opinion that the best probable chance of success is to found a new pier upon the ruins of the old, and to make the superstructure as light as possible; the particular methods of doing which I have pointed out to Mr. JOHN BROWN, mason of the said bridge; and as the other piers and arches seem to stand firm, I think in the above way there is so far a reasonable prospect of success as to deserve to be attempted.

Dumbarton, May 31, 1768.

J. SMEATON.



LEWES

LEWES LAUGHTON LEVEL.

The REPORT of JOHN SMEATON, Engineer, concerning the Drainage of *Lewes Laughton Level*, in the County of *Sussex*.

HAVING carefully viewed and examined the state of this level, upon the 17th, 18th, 19th, and 20th days of June, 1767, I found its condition as follows :

The preceding part of the season having proved wet, the level meadows called *Brooks*, laying upon the river *Ouse*, were in general under water from *Land Port*, above *Lewes*, to *White Wall*, below *Rodmill*. I observed that the surface of the water in the brooks of *Southover*, *Iford*, *Pool Bar*, *Skine*, and *Rodmill*, was nearly upon one common level, which several tracts of ground, for the ease of expression, I beg leave to call by the general name of the *West Level*: That there was but an inconsiderable fall of the surface of the water from the west level into the river, when the tide was down, and was some inches below the surface of the river when the tide was in: the same observation equally applied itself to *Ranfcombe*. That the artificial banks or walls contiguous to the river bordering on both these levels, were low, and in very bad condition, so that if the river was to swell 6 inches higher than it then was, the two levels and river would have one common surface. I observed, at the same time, that the lands below *White Wall*, from the south-east downwards, on the west side, and those of *Tarring* on the east, were in general dry, and in a tolerable state of drainage, which preferable condition thereof was undoubtedly owing to these three causes: the land itself is considerably higher, the banks made up higher, and in better repair; and their out-fall sluices fixed lower upon the river, which in consequence affords them a better fall.

It was observable during my stay, the tides being then in a mean state betwixt spring and neap, and the river pretty full of water, that the tides were scarcely sensible at *Lewes Bridge*, and but a few inches rise and fall at the mouth of the river *Glynd*; while at the sheep-wash above *Piddinghoe*, the tides rose and fell 5 feet, and not above half a mile below, at the head of the *Broad Salts*, the rise and fall was near 8 feet; the greatest part of the whole fall lying betwixt the last-mentioned place and *White Wall*, a space not above $2\frac{1}{2}$ miles, according to the course of the river, and which includes at least $\frac{2}{3}$ of the whole fall, from *Lewes Bridge* to the head of the *Broad Salts*, which is a length of near 7 miles. This great declivity in the river from *White Wall* to the *Broad Salts* is doubtless owing to a series of shoals laying in that space, the principal of which is *Piddinghoe*, which alone occasions a fall of 3 feet, and which, as well as the narrowness and winding

winding course of the river, altogether occasion the holding up the water in the river above *White Wall*, and which in consequence oppresses the levels laying thereupon, and still the more in proportion as their natural surfaces lay 2 feet at an average lower than the grounds below *White Wall*.

From the head of the *Broad Salts* downwards, the river is more spacious and open, and wherein the tides have full liberty to flow and reflow, and may be considered as an open tide's way. The declivity of the surface at low water is very gentle, till we come near the harbour's mouth of *Netobaven*, where the river *Ouse* falls into the sea, and where the water is held up by a bank of shingle, thrown in by the great seas and tides, and in part washed out again by the united force of the freshes and reflux of the tides, and which finds a balance betwixt these contrary powers, being somewhat variable according as one or the other happens to have the prevalence. From the surface of the water above this bank or bar, that is, from the surface of the water in the pool where the ships lay, called *Sleeper's Pool*, I found a fall of $6\frac{1}{2}$ feet to the low water mark at sea, which at spring tides is still greater.

The state of the brooks above, or north of *Lewes Bridge*, and which for the sake of a general name I beg leave to call the *North Level*, was as follows: they were almost entirely under water, as high up as *Land Port*; from thence up as high as *Iron Hole*, they were in part under water; but in general where no water upon the surface, low and moist, and the appearance of being oppressed with water a too great length of time; but from thence to *Barcombe* mill, the meadows lay considerably higher, being in general 3 or 4 feet above the surface of the river, as it then was; however, as the whole course of the river through the *North Level*, from *Barcombe* mill to *Lewes Bridge*, has but an inconsiderable fall, is very crooked and winding, and in some places obstructed with shallows, the upper as well as the lower part of this level must be subject to be flooded on moderate down-falls of rain.

With respect to the brooks upon the river *Glynd*, eastward of *Ranscombe*, they appeared to be in general above water, but yet subject to too great a continuance of flagrant water upon them, partly from want of a sufficient fall in the river *Glynd*, and partly from crookedness and obstructions therein; however, as they appeared in general so much higher, that by whatever means the drainage of *Ranscombe* would be effected, must necessarily furnish the means of draining those brooks, I was less solicitous about the exact state of particulars.

It appears moreover, from trying the different depths of the water in the different brooks, that the deepest under water were *Ranscombe* on the east side, and the S. E. part of *Isford* and part of *Rodmill* brooks in the west level, the general surface of those low parts being then about 3 feet under water.

From this general view of the state of the level, it would seem, that if the obstructions arising from the several shallows from the narrowness and crookedness of the river, between the mouth of the river *Glynd* and the top of the *Broad Salts*, were removed, which have been described to be the cause of the holding up of the river at and above the aforesaid limits, that the consequence would be a general drainage of all the levels; and it is certain, if these things were done, that this alone would be a great help to the whole of the grounds in question; but yet, as the taking away these obstructions would in consequence let the tides flow in with more rapidity, the natural declivity of the river being small, there would be scarcely time for the tide and fresh water to evacuate itself, before another tide would return, and thereby prevent its ever running so low as to admit of a compleat drainage of the adjacent levels.

Towards an effectual drainage of these levels, two methods offer themselves; one is to straighten the river, and remove all obstructions as before described, and furthermore, to prevent the tides from having the effect abovementioned, to place a large out-fall sluice at its entrance into the open tide's way, with gates to shut out the tides from flowing up the river, and of sufficient dimensions to discharge the fresh waters at their greatest extremity; and lastly, to embank *Ranscombe* and the west level against the overflow of the land floods, so as to convey the flood waters directly to sea, placing sufficient sluices upon their respective out-falls into the river, so as to shut out the land floods, and give an opportunity of drainage when these floods are run off, which they will easily do, when not suffered to spread upon the adjacent levels; and indeed, without embanking those levels as aforesaid, every method of drainage will be no more than a palliative help.

The second method supposes the river to remain in its present course, or without great alteration, to embank the lands to be drained against all extreams of floods, and to convey their internal down-fall waters by a separate canal or sewer to the open tide's way, with a sluice upon the out-fall of the said canal, to prevent the reflux of the tides.

Each of these methods have their particular advantages; the first seems better adapted to give all the succour possible to the *All Country* dependant on this out-fall; the second is more particularly adapted to the drainage of *Ranscombe* and the west level, the north
and

and east levels being less advantageously situated by nature for drainage this way, as will more particularly appear from a further description and estimates that will follow of each method.

From an accurate level taken the 18th and 19th of June last, it appears as follows :

	Feet	In.
Rise from low water to the head of <i>Broad Salts</i> , to the surface of the water in the west level,	6	5
The river being then charged with fresh water, the low water surface at <i>Broad Salts</i> was said to be 2 feet, at least 18 inches above its low water height in dry seasons, but taking it at - -	1	0
Rise from low water at the <i>Broad Salts</i> in dry seasons to the surface of the water in the west level,	7	5
The mean depth of water in the low parts of the west level and of <i>Rancombe</i> , (subtract)	3	0
Rise from low water in dry seasons at the head of the <i>Broad Salts</i> , to the mean surface of the low parts of the west level and <i>Rancombe</i> ,	4	5
Now in order to produce a compleat drainage of those low grounds, it will be necessary to reduce the surface of the water, below the surface of the ground, - - -	2	0
There will then remain - - -	2	5

It therefore appears that the water may, in dry seasons, be retained in the river 2 feet 5 inches above low water in the tide's way, and yet the surface reduced full 5 feet below the height it was in June 1767 ; and as the deepest parts of the pool in *Rancombe* (which is deepest of all) sounded only 4 feet 6 inches, it follows that the water may be reduced in the drains 6 inches below the bottom of the pool in *Rancombe*.

In regard to the 2 feet 5 inches of water retained in the river above low water, it will be useful for navigation in dry seasons ; and in small freshes, by affording so much fall, will thereby give the river a better current to sea, without overcharging the drains. In larger freshes, and great downfalls, the river's water will be prevented from over-riding the drains by their respective sluices, and the water will quickly discharge itself to sea, on account of its being confined between the banks, which are proposed to be made to prevent the rivers from overflowing the adjacent levels, as they do at present.

To effect these purposes, I would propose a new cut or river to be made across a corner of *Tarring Tenantry*, by which means *Piddinghoe* shoal will be avoided : a sluice is to be placed at the tail of this cut of three passages, 2 of 13 and 1 of 14, containing in the whole 40 feet clear water-way ; the latter passage to be furnished with a double pair of pointing doors to seaward, and ditto to landward, for the sake of navigation ; the other passages each to be furnished with a single pair of pointing doors to seaward, to shut out the tides, and a single pair to landward, to retain the fresh waters at a given height in dry seasons.

A dam

A dam to be put across the river at *Piddinghoe* sheep-wash, so as to shut out the tides, and to prevent the floods from passing that way after the aforefaid works are erected *.

In order to avoid a crooked part of the river in passing by *Itford* and *Stockhouse*, containing a number of shoals, I propose to cut a new river from *Stockferry* to the turn below the *White Wall*, of the same dimensions as the former.

All the other shoals I propose to deepen, so as not only to lower the surface of the water at *Lewes Bridge* from 4 to 5 feet, but also to make full 3 feet 3 inches water over the shallows in the driest seasons, which will be a great improvement to the navigation, as vessels will not be stopped by neap tides in dry seasons, nor obliged at any time to wait for the tides betwixt the sea sluice and *Lewes*.

These works being effected, all the levels in question will be in a *capacity* of drainage, so that each performing the particular works that relate to themselves, the whole will be in a condition of improvement.

As the west level and *Ranscombe* lay considerably lower than the rest, it is impossible they should be in a good state of drainage without being embanked against the freshes and floods of the river *Ouse* and *Glynd*; but instead of setting the banks close upon the river, I would, in the general, leave a space of 50 feet between the bank and the river, however varying this quantity, so that without following the sudden turns of the river, the bank may be reduced in length; observing, that where the bank is near the river on one side, it be put further off on the other, still forming an open space to give room for the passage of the floods in wet seasons.

According to this method, there will still be a necessity of sluices for the particular drainage of each tract of embanked land, to shut against the river in time of floods. Those already constructed might have answered the purpose had their thresholds been laid low enough, but as the thresholds of *Shine* and *Ranscombe* sluices, which lay the lowest, are at a medium but about 2 feet below the mean surface of the lowest lands respectively, they are insufficient for an effectual drainage, because before the water can come down to its proper pitch of level for drainage, its thickness over the thresholds will be so much diminished, as not to afford the water a sufficient passage. I therefore

* It is to be observed, however, that if there should happen to be any solid objection to putting a dam across the river at *Piddinghoe* sheep-wash, that the same purpose may be effected by putting sluices, instead of a dam at the sheep-wash, in which case there will need no more than the 14 foot passage for the joint purposes of navigation and drainage upon the new cut proposed across *Farring* brooks.

recommend

recommend a new sluice of brick for the west level, to be placed down as low as the *White Wall*, and another for *Ranscombe*, near the mouth of the river *Glynd*, their thresholds to be laid 2 feet lower than those of the sluices abovementioned respectively.

In regard to the internal drains, what will be wanted further will be in the west level, one to join the sluice at *Kingstone* sewer, which sewer, when properly scoured out, will drain the western parts of the level; and those parts laying near the river, as far north as *Cockbutt*, will be drained by the back drain, which will of course be formed, by taking the matter for embanking. In *Ranscombe* a new drain must be made, or the old ones scoured out from the sluice to the pool; but the back drain of the bank will be an effectual drainage for all the parts of the level near the river.

This is the whole, therefore, that can be expected to be done at a joint expence in these two levels; the division and other drains are to be made by the respective proprietors, at their particular expences, and which I don't consider as any part of the object of this report.

At the time of my view the river had but an inconsiderable fall from *Lewes Bridge* to the mouth of the river *Glynd*, so that when the shallows are removed, the water in the river, as already mentioned, will, in its ordinary state, be reduced 4 feet at *Lewes Bridge* below what I found it*, and sometimes near 5, so that in the *Lewes* brooks above *Cockbutt*, the ordinary surface of the water in the river will be about 3 feet below the surface of the land; and in the brooks north of *Lewes Bridge* from $3\frac{1}{2}$ to 4 feet and upwards; so that, taking away some shoals above bridge to facilitate the passage of the water, I look upon all these brooks as in a state of drainage, liable, indeed, to be overflowed upon great downfalls of rain; but as, according to this construction, these downfalls will speedily run off, and leave the meadows dry, they will be liable to no other inconveniencies than what waterside meadows generally are; what little banking or drainage will be further necessary for their security, I suppose to be left to the discretion and management of each particular proprietor.

The same reasoning will hold with respect to the brooks upon the *Glynd*, east of *Ranscombe*, for the water being reduced from the surface, I found it full 5 feet perpendicular at the out-fall of the *Glynd* into *Ouse*, there will be little further to do, than to scour out the river *Glynd*, so as to take advantage of the falls so obtained; the scouring out of the river *Glynd* I look upon as a work particular to the brooks east of *Swale*

* The water under *Lewes Bridge*, when the levels were taken, was 3 feet $8\frac{1}{2}$ inches below the top of the aisle courses of the S. E. wing of the bridge.

Bank; and what further banking and draining may be necessary, I in like manner suppose to be the work of the respective proprietors, and not the object of this scheme, which is to point out the general methods by which the whole will be put in a *capacity* of drainage, not to drain the lands, ready for the husbandman.

I have already shewn that the work of the drainage thus constituted will be advantageous to the navigation of the river for the barges, and an advantage for which, in my opinion, they ought to pay a toll towards the ease of the general undertaking: it now remains to shew that the constructions proposed will be no ways detrimental to the harbour of *Newhaven*; on the contrary, I propose to demonstrate, that it will be a considerable advantage, upon the principles of the first scheme now described, for as to the second it cannot be made a question.

I know it will be immediately apprehended, that the tides being stopped at *Piddinghoe*, will occasion a less influx of the tide at the mouth of the harbour; and as a less influx will produce a less reflux, the power will thereby be diminished, by which the sand, shingle, &c. is driven out to sea, that is brought into the harbour's mouth by storms and hard gales of wind bearing strong upon the coast; but this reasoning, however plausible it may appear, and however true it may be in some cases, yet in the present it will not hold; but I must observe, that if admitted, the quantity in question is so small in proportion to the whole, that its effects can produce no sensible difference in the scour of the harbour; the quantity of tide water then in question will be only such as flows into and out of the river above *Piddinghoe* shallow; this, at the time I was there, amounted to a rise and fall of 5 feet, as already stated at *Piddinghoe* sheep-wash, but at *White Wall*, not $2\frac{1}{2}$ miles up the river, the rise and fall were not above a foot, and at *Lewes Bridge* scarcely sensible, so that the greatest part of the influent water was contained in about $2\frac{1}{2}$ miles of river, at the mean depth of 3 feet, and at a mean width not exceeding 30 or 35 feet *, which will evidently bear but a small proportion to the water contained in the river from the pier of *Newhaven* to *Piddinghoe*, where the mean rise and fall was three times as great, the mean breadth more than double, nearer three times, and the length above three miles, besides the water flowing a considerable breadth near a mile up the old harbour, as far as the tide mill: this would be the proportion, supposing all the tide's water above *Piddinghoe* to be quite lost; but the real quantity of reflux lost by the river above *Piddinghoe* will be greatly diminished, below what is

* I am sensible that in dry seasons, when there is less land water in the river, the rise and fall of the tides will be greater, and be sensible further up the country; but as the efflux will be less for want of the land water, the effect in scouring must be less than at the time above stated.

above stated, when it is known that the tide at *Piddinghoe* did not rise so high by above a foot (I made it 1 foot 3 inches) as it did at the pier head the same tide; from whence it follows that the tide having room to spread and spend itself faster than it can be supplied at the mouth, the ponds within are never filled within 6 or 7 inches at a medium so high as they would be if they were so much less, as to have time to fill to the level of the tide at sea: we have therefore grounds to say, that if the tide was prevented from spending itself so far up the river, it would occasion the remaining space to fill to a higher level, and thereby take in a quantity upon the whole nearly as large as if suffered to flow further; and that this reasoning is true, further appears from this fact, that in spring tides the water gets so far up the river, that not having tide to get back again, the same tide fills the river above *White Wall* fuller and fuller, which is not evacuated but by the neaps that succeed*.

From what has been said we may be assured, that the stop of the tides at *Piddinghoe* could be of no great consequence to the harbour, even upon a supposition that the tide water there lodged is *useful* towards clearing the harbour's mouth, which I come now to shew that it is not, but in the present case detrimental.

When the wind is *in shore*, and brings an heavy sea upon the harbour's mouth, the shingle is thereby put in agitation; and if a strong tide of flood happens during such violent agitation, the indraught of the tide brings in a quantity of shingle, and loads the entry of the harbour, and this effect will (*ceteris paribus*) be greatest when the indraught is strongest, that is, when there is the greatest tides, and the least fresh water in the river to oppose them; and this indraught will also be strongest, when there is a narrow entry, and a great space wherein the water may expand itself; for there the tides of flood will set in through the harbour's mouth the most rapidly. These circumstances concur in a strong degree in the present case, and therefore a diminution of their *expansion* must diminish the *rapidity of tide of flood*; at such a time when the river has no great currency downwards, the tides, as already observed, instead of returning wholly to sea, are spending themselves up the river to *Lewes*, which occasions a rapid influx, and a languid efflux; the river is therefore at this time in no condition to evacuate the shingle so brought in; here it must lie till something happens to turn the balance the contrary way, and this is done by the land floods joining with the tides, which promote a brisk reflow to sea. Now at such times, the land floods will at *Piddinghoe* *over-ride* the tides, and the sluice doors will be open the whole time of tide; the sluice therefore will not in any respect impede the land floods from getting to sea, and by the embanking

* N. B. The high water before referred to was near 1 foot higher at *Piddinghoe* than it was at *Lewes Bridge*.

of the river, they will be brought down with greater rapidity, and thereby produce a scour superior to what it can obtain in the present state of things. Since therefore the rapidity of the tide of flood will be diminished, and the ebb tide increased, at such times when alone they can be of use in scouring, the effect upon the clearing of the harbour's mouth must be beneficial *.

I come now to describe the second method of drainage, whereby the river will be left in its natural course; and whereby, if the drainage of the west level and *Rancombe* were the only objects in view, the work would be done at the easiest expence, as will be more particularly seen by the estimates.

This consists of an entire embankment of the rivers against all extremes of floods, so far as the drainage is carried, thereby shutting the river entirely out; so that instead of discharging the down-fall waters into the river at the point opposite the respective tracts of ground, it is to be collected into one drain, and finally discharged into the open tide's way by means of a sluice, which, shutting out the tides, prevents at once the reversion of the water for the whole level. This sluice and drain will be far less in point of water-way than that before proposed, having nothing to convey to sea but the down-fall water of the levels to be drained; whereas the other must be large enough to afford a sufficient passage to sea to the flood waters of the whole river in the greatest extremes of floods. This second method is in many cases to be preferred, as it stands clear of all difficulties respecting the altering the current or navigation of the river, and is in itself *most perfect*; but in the present case the north and east levels are situated so disadvantageously, with respect to their communication with the general out-fall, that to accomplish the whole in this way will be more expensive than by the first method. But to proceed:

I propose the out-fall sluice to be nearly at the same place of the river as before proposed, and to be of 12 feet water-way; from hence a drain of 12 feet bottom to be carried through *Tarring Tenantry*, and by means of a subterraneous tunnel, to cross the river *Ouse* in a proper point between *Stock Ferry* and *Stockhouse*, from thence through the low grounds of *South Ease*, and cross the *White Wall* to a point of division in *Rodmill Tenantry*, there to branch off in three directions; the N. W. branch to fall in with *Kingston* drain; the north branch to pass between the two *Ries* to bring down the cock-shot water, which will be useful for the cattle, and prevent its being particularly embanked; from thence through *Lewes* brooks below bridge, and under the river *Ouse* in a subterraneous tunnel, answerable to one of the old passages that cross the street east of *Lewes*

* By fixing doors proper for that intent, this sluice may be made useful for procuring artificial scours at low water in dry seasons.

Bridge; from thence through the *Malling* brooks, and again crossing the river into *Lewes* brooks above bridge, from thence upland port brooks, skirting the river with a bank and drain (without following the minute windings) as far as the drainage is wanted to be carried, which, on the west side, I have supposed to be as far up as the iron-hole; for the sake of the brooks east of the river another tunnel will be necessary to convey their drainage across the *Ouse* a little above Mr. KEMP's, and thence skirting the river with bank and drain as on the east side, as far as the artificial drainages are wanted, which I have supposed to be the *Carp-Hole* or *Horfe-shoe* brook.

Returning now to the point of division, the N. E. branch is intended to cross the river *Ouse* by a subterraneous tunnel, and proceed directly to the pool in *Ranscombe*, from thence proceeding eastward to cross the boundary of *Ranscombe*, and after that skirting the river *Glynde* with a bank and drain on the north side till we are past the turn-pike-road, and the brooks grow broad and open on the south side the river; from this point the drain is to be pursued on the north side, supposed to *Edley*, for draining the great hoof, &c. crossing the *Glynde* from the said point, by a subterraneous tunnel, and in like manner carrying a bank and drain on the south side; this will serve for a drainage of the *Firle* brooks, and what else on that side of the river may be further necessary.

The *Beddingham*, *Asom*, and *Itford* brooks are also to be drained by a subterraneous tunnel under the river *Glynde*, to communicate its drainage with *Ranscombe*.

The carrying the drainage through the *South-Ease* and *Tarring* brooks may possibly be objected to, as bringing the waters upon them; but as they lay higher than the rest, and the earth dug out of the drains forming, of course, a much more than sufficient barrier bank, they cannot possibly receive any prejudice, but, on the contrary, will have their drainage rendered more effectual by draining into the new cuts proposed to pass through them.

J. SMEATON.

Ausborpe, 27th July, 1768.

P. S. The general level, as taken the 18th and 19th of June, 1767, from the sea to *Lewes Bridge*, the latter being the moon's quarter-day, was as follows :

	Ft.	In.
Rise from the sea (at a flowing water) to the pier head at <i>Newhaven</i> , - - -	4	0 $\frac{1}{2}$
From the pier head to <i>Sleeper's Pool</i> , - - -	1	8 $\frac{1}{4}$
From <i>Sleeper's Pool</i> to the top of the <i>Broad Salts</i> , below <i>Piddinghoe</i> , by estimation, - -	0	10
From low water surface, at the top of the <i>Broad Salts</i> , to the water's surface in the west level near <i>Skine sluice</i> , - - -	6	5
Rise from the surface of the west level water to the surface of ditto, at <i>Lewes Bridge</i> , by estimation, - - -	0	4
	<hr/> 13	<hr/> 4

N. B. On comparing the high water mark at the pier head at *Newhaven* on the 17th, with the foregoing levels it appears, that the high water at the pier head was above the level of the surface of the water at *Lewes Bridge* the same day 2 feet 2 inches.

ESTIMATE for *Lewes Laughton Level*, upon the principles of the first scheme.

GENERAL WORKS.

	£.	s.	d.
To a sea-sluice of 40 feet water-way, containing three passages, two of 13 feet each, with pointing doors to seaward to keep out the tides, and ditto to the land, for holding up water for the navigation in dry seasons, and one passage of 14 feet, to be furnished with a double pair of gates pointing to seaward, in order not only to keep out the tides, but to form a navigable lock to let the vessels pass at all times; to be built with brick, with stone quoin and facings, the thresholds to be laid 2 feet below low water mark, in that part of the river opposite the sluice, - - -	4000	0	0
To cutting a new river opposite <i>Piddinghoe</i> , to be 27 feet bottom, and sloped in proportion of 3 to 5, (that is 3 perpendicular to 5 horizontally) and being 9 $\frac{1}{2}$ feet deep, will be 59 feet at top, and which, for 4 furlongs 3 chains length, will contain 42,948 yards, at 5 <i>d.</i> including drainage, - - -	894	15	0
To 7 $\frac{68}{100}$ acres of land for the cut and cover, the cover being supposed at half value, is reckoned at half quantity; the value per acre I do not pretend to judge of, but if, for the sake of estimation, it be reckoned at 40 <i>l.</i> an acre, this will come to, - -	307	4	0
To a new cut from the turn of the river below <i>White Wall</i> , to the turn of the river above <i>Stock Ferry</i> , being of the same dimensions as the other, and 4.6 furlongs in length, will, at the same price, come to - - -	957	3	9
To 8 $\frac{22}{100}$ acres of land, at the same price, cut and cover, - - -	328	16	0
In order to prevent the necessity of letting in the tides, for the sake of the navigation in dry seasons, and also to give the water a more free passage in its lowest state, it will be necessary to deepen the following shoals, viz. <i>Dean shallow</i> , <i>Sound shallow</i> , <i>Bramble Bush ditto</i> , <i>Snow ditto</i> , <i>Cliff ditto</i> , and <i>Tafall ditto</i> , these at 100 <i>l.</i> each, will come to -	600	0	0
General works, - - -	7087	18	9

Parti-

Particular Works for the Levels west of the *Ouse*, below *Lewes-Bridge*, and on both sides above, on north of ditto.

	£.	s.	d.
To making new banks on the west side of the river, from the head of the new cut below <i>White Wall</i> , to the high land at <i>Southover</i> , being in length 28 furlongs, to be at a medium 24 feet feat, 6 feet top, and 6 feet high, the matter being taken out on one side, so as to form a back drain, at 3 <i>d.</i>	770	0	0
To land to be converted into a drain, in order to make the bank, (the land being low, I reckon no spoil of land by the cover of the bank,) this, for 28 furlongs length, will be 10.1 acres, which, if valued at 15 <i>l.</i> per acre, will come to	151	10	0
To making a new sluice of 6 feet clear water-way on the north side of <i>White Wall</i> , the threshold to be laid two feet lower than <i>Shine</i> sluice, to be built of brick, with stone facings,	300	0	0
To making a drain from the new sluice to join <i>Kingston</i> sewer, to have a 6 feet bottom, slopes as 3 to 4, and, at a medium, 5 feet deep, this, for 7½ furlongs, at 2½ <i>d.</i> per yard, including drainage, is	120	6	3
To land to be cut for the said drain, the land being low, I reckon no damage for cover 2½ <i>s.</i> acres, which if reckoned at 15 <i>l.</i> per acre,	33	0	0
To taking out four shallows above <i>Lewes</i> , that obstruct the regular course of the current, viz. the washing-place opposite <i>St. John's</i> , <i>Bell Shallow</i> , above Mr. <i>HEMP'S</i> , <i>Stoneham</i> sheep-wash, and <i>Hansey Flats</i> , at 50 <i>l.</i> each,	200	0	0
Particular expence of the west and north levels,	1574	16	3

Particular Works for *Rancombe Level*, and Level on the *Glynde*, on the east of the *Ouse*.

To embanking <i>Rancombe</i> , from the high lands at <i>Walker's Hole</i> , 10 furlongs, and up the river <i>Glynde</i> to <i>Swale Bank</i> , 9 furlongs, of the same dimensions and price as before,	522	10	0
To 6½ acres of land, to be converted into a drain to make the bank, at 15 <i>l.</i>	102	12	0
To a new sluice at <i>Rancombe</i> of 4 feet clear water-way, the threshold to be laid 2 feet lower than the threshold of the present sluice, to be built as the former,	200	0	0
To embanking of <i>Rancombe</i> as before proposed, supposes the matter to be taken at the greatest convenience all round, but for the more perfect drainage of the brooks upon the <i>Glynde</i> , above <i>Swale Bank</i> , it will be necessary to take out a part of the earth from the river <i>Glynde</i> , in order to dyke it out; the extra expence, therefore, in dyking out the river <i>Glynde</i> , from its mouth to <i>Swale Bank</i> , and therewith in part making the bank alongside, so as to make it 1 foot deeper than the present threshold of <i>Rancombe</i> sluice, may be set at	90	0	0
To dyking out and scouring the river <i>Glynde</i> , from <i>Swale Bank</i> to the west end of the <i>Great Hoof</i> , for procuring a general out-fall to the eastern brooks, being in length 12 furlongs, that is 480 roods, at 10 <i>s.</i>	240	0	0
Particular works for <i>Rancombe</i> , and levels on the <i>Glynde</i> ,	1155	2	0

A B S T R A C T.

	£.	s.	d.
General Works,	7087	18	9
Particular expence of the west and north levels,	1574	16	3
Particular works for <i>Ranfcombe</i> , and levels upon the <i>Glynde</i> ,	1155	2	0
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Upon the above we may allow 10 per Cent. for unforeseen accidents, and contingent works not brought to account in the above, together with utensils and supervifal,	9817	17	0
	981	15	8
	<hr/>		
	10,799	12	8
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SECOND ESTIMATE for *Lewes Laughton Level*, upon the principles of the second scheme.

GENERAL WORKS.

	£.	s.	d.
To the sea sluice at the tail of the main drain of 12 feet clear water-way, the threshold to be laid 1 foot below low water mark, with pointing doors to seaward, and draw gates to landward, for holding up water in dry seasons for the use of cattle, to be built with brick, with stone facings,	1200	0	0
To the main drain, to be carried as per plan, through <i>Tarring Tenantry</i> to <i>White Wall</i> , to have a 12 feet bottom, slopes as 3 to 4, to be dug as deep as the fill of the sluice, that is at a medium $8\frac{1}{2}$ feet deep, the length being 15 furlongs, at $4\frac{1}{2}d.$ per yard, including drainage,	1361	5	0
To putting a subterraneous tunnel across the river <i>Ouse</i> , in the reach between <i>Stock Ferry</i> and <i>Stockhouse</i> , of 12 feet water-way,	1000	0	0
To continuing the main drain from <i>White Wall</i> to the point of division, bottom and slopes as before, the depth being about 6 feet, and $5\frac{1}{4}$ furlongs length, at $4d.$ including drainage,	268	17	7
To purchase of lands from the out-fall sluice to <i>White Wall</i> , cut and damage of cover at 66 feet broad, and 15 furlongs length, will contain 15 acres, which, if estimated as before at $40l.$ will come to	600	0	0
To purchase of lands for the cut from <i>White Wall</i> to the point of division, (the land being low, I reckon no damage of cover) at 27 feet breadth, and $5\frac{1}{2}$ furlongs length, make $2\frac{1}{8}$ acres, which, if valued at $15l.$ per acre, comes to	34	5	0
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General works,	4464	7	7
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ESTIMATE of works to be done in the west level.

	£.	s.	d.
To continuing the drain from the point of division, up to meet <i>Kingston</i> sewer, upon a 6 feet bottom; the batters 3 to 4, and at a medium 5 feet deep; this for 2.4 furlongs, at $2\frac{1}{2}d.$ per yard, including drainage, comes to	38	10	0
To land for the drain to join <i>Kingston</i> sewer, containing $\frac{3}{80}$ acres, at 15 <i>l.</i>	5	5	d
To embanking the river <i>Ouse</i> from <i>White Wall</i> to the top of <i>Lewes</i> brooks below bridge, to be at a medium 24 feet feat, 6 feet top, and 6 feet high, at 3 <i>d.</i> per yard; the forming a back drain included, will, for 30 furlongs, come to	825	0	0
To $10\frac{8}{10}$ acres of land, converted into a drain for forming the aforefaid bank, at 15 <i>l.</i>	162	0	0
To cutting a new north sewer, from the point of division to its junction with the bank drain, to have a 6 feet bottom, batters as 3 to 4, and five feet mean depth, containing 11 furlongs in length; this at $2\frac{1}{2}d.$ per yard, including drainage, comes to	176	9	2
To land for the above cut, no spoil of cover, containing $3\frac{2}{100}$ acres, at 15 <i>l.</i> per acre,	48	6	0
Particular charge of the west level,	1255	10	2

Estimate for the north Brooks above *Lewes Bridge*.

To making a 5 feet tunnel across the river, at the head of <i>Lewes</i> brooks,	600	0	0
To making a sewer of 6 feet bottom, with slopes as 3 to 4, and therewith forming a bank, by laying the earth on one side, at a medium 5 feet deep, will make a bank 20 feet feat, 5 feet top, and 5 feet high; this at $2\frac{1}{2}d.$ per yard, cutting and banking included, for 30 furlongs, from the river opposite the head of <i>Lewes</i> brooks, below bridge, to the iron hole at the head of <i>Hansey</i> farm,	481	5	0
To land for the above sewer, containing $8\frac{8}{10}$ acres, at 15 <i>l.</i> an acre, no spoil allowed for banks,	132	0	0
To probable extra expences in the cut passing the street east side of <i>Lewes Bridge</i> ,	250	0	0
To a 5 feet tunnel to pass the river, from <i>Malling</i> brooks to <i>Lewes</i> brooks, above bridge,	500	0	0
To a 3 feet tunnel to pass the river above Mr. KEMP's, to communicate the drainage from the east side,	400	0	0
To making a bank and sewer from the said tunnel on the east, to the <i>Horfe-Shoe</i> brooks, of the same dimensions as the former, being 21 furlongs,	336	17	6
To land for the above drain $6\frac{1}{100}$ acres, at 15 <i>l.</i>	92	5	0
North brooks	2792	7	6

Estimate for the drainage of *Ranscombe*.

To cutting a main drain, from the point of division to <i>Ranscombe</i> pool, to have a 6 feet bottom, batters as 3 to 4, and at a medium of 5 feet deep, the length being $8\frac{1}{2}$ furlongs, at $2\frac{1}{2}d.$ per yard,	136	7	1
To land for the above cut, containing $2\frac{4}{100}$ acres, at 15 <i>l.</i>	37	7	0
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	£.	s.	d.
Brought forward, - - -	173	14	1
To making a 6 feet tunnel across the river <i>Ouse</i> , - - -	800	0	0
To embanking <i>Rancombe</i> , from the high lands at <i>Walker's Hole</i> , by the river <i>Ouse</i> , to the <i>Glynde</i> , and up the river <i>Glynde</i> to <i>Swale Bank</i> , to have a 24 feet seat, 6 feet top, and 6 feet high; this for 19 furlongs, at 3 <i>d.</i> per yard, back drains included, comes to - -	522	10	0
To 6,84 acres of land, occupied by the drain from whence the bank is to be taken, at 15 <i>l.</i>	102	12	0
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Particular charge for <i>Rancombe</i> , - - -	£. 1598	16	1
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Charge of draining the east brooks, or brooks east of *Rancombe*, as also those of *Beddingham*, *Afem*, and *Itford*.

To cutting a drain, from <i>Rancombe</i> pool to the east extremity of <i>Rancombe</i> , to have a 6 feet bottom, slopes as 3 to 4, and at a medium 5 feet deep; this, for 6 furlongs, at 2 $\frac{1}{2}$ per yard, will come to - - -	96	5	0
To land for the above 1 $\frac{7}{16}$ acres, at 15 <i>l.</i> - - -	26	8	0
To cutting a drain of 6 feet bottom, with slopes as 3 to 4, and therewith forming a bank against the river <i>Glynde</i> , by laying the earth on one side, at a medium 5 feet deep, will make a bank of 20 feet seat, 5 feet top, and 5 feet high; this, for 18 furlongs from the head of <i>Swale Bank</i> , through the <i>Great Hoof</i> to <i>Horfe Brook</i> , at 2 $\frac{1}{2}$ <i>d.</i> per yard, will come to - - -	336	3	0
To land for the above drain 5 $\frac{3}{16}$, at 15 <i>l.</i> - - -	79	0	0
To putting a 3 feet tunnel across the river <i>Glynde</i> below the <i>Great Hoof</i> , in order to communicate the drainage of <i>Firle</i> brooks with the former drain on the north side, - - -	150	0	0
To embanking the <i>Firle</i> brooks against the river <i>Glynde</i> , opposite the <i>Great Hoof</i> , and therewith forming a drain, supposed of the same dimensions as the north side; this for 9 furlongs, will come to, - - -	144	7	6
To land for ditto 2 $\frac{6}{16}$ acres, at 15 <i>l.</i> - - -	39	12	0
To putting a tunnel across the river <i>Glynde</i> , in order to drain <i>Beddingham</i> brooks, of 3 feet water-way, - - -	200	0	0
To embanking those brooks against the river <i>Glynde</i> , and thereby making a drain behind the bank, which is to have a 24 feet seat, 6 feet top, and 6 feet high; this, at 3 <i>d.</i> per yard; for 7 furlongs, will come to - - -	192	10	0
To land for the above drain 2 $\frac{1}{16}$ acres, at 15 <i>l.</i> - - -	37	16	0
To embanking <i>Afem</i> and <i>Itford</i> brooks, against the river <i>Ouse</i> , and thereby making a drain behind the bank to communicate with that of <i>Beddingham</i> , being in length 14 furlongs, which being of dimensions and price as <i>Beddingham</i> , will come to - - -	385	0	0
To land for the above drain 5 $\frac{1}{16}$ acres, at 15 <i>l.</i> - - -	75	12	0
	<hr/>		
Particular charge of the brooks upon the <i>Glynde</i> , exclusive of <i>Rancombe</i> , - - -	1762	13	6
	<hr/>		

Abstract of the drainage of *Lewes Laughton Level*, by the second method.

	£.	s.	d.
The general works for bringing the drainage to the point of division in the west level,	-	4464	7 7
The particular charge of the works for the drainage of the west level,	-	1255	10 2
Estimate for the north brooks above <i>Lewes Bridge</i> ,	-	2792	7 6
Estimate for the drainage of <i>Rancliffe</i> ,	-	1598	16 1
Charge of draining the brooks east of <i>Rancliffe</i> , as also those of <i>Beddingham, Afem</i> , and <i>Isford</i> ,		1762	13 6
Upon the above we may allow 10 per cent. for unforeseen accidents and contingent works			
not brought to account in the above, together with utensils and supervisal.	-	1787	7 6
		<u>13061</u>	<u>2 4</u>

Amthorpe, July 27, 1768.

J. SMEATON.

A S H I P ' s P U M P .

DESCRIPTION of a Ship's Pump, designed by JOHN SMEATON, Engineer.

A Pump of this construction was designed in the year 1765 by Mr. SMEATON, and executed from his directions by Mess. HURREY and Co. at *Howden Dock*, upon the river *Tyne*, the latter end of the same year, which meeting with the approbation of the master of the ship on board which it was first fixed, who reported that it had actually saved the ship, some others have since been made nearly similar by the same company, but the superior expence has hitherto prevented so great a demand as might have been expected. In the present design, in which the whole has been carefully reconsidered, I have not rigidly adhered to the particularities of the first construction, but altered such smaller matters as convenience seemed to suggest.

Besides the advantages that were expected to accrue above the common form from better mechanism and proportion of the parts, the following was in view: the common ship's pump in general delivers its water upon the main deck, which, according to the largeness and construction of the ship, is 4, 5, and 6 feet above the load water line; at the same time that the load water line is not above from 14 to 18 feet above the ship's bottom; it therefore appears, that the ordinary pumps lift the water from $\frac{1}{4}$ to $\frac{1}{4}$ higher than the level at which the water might be delivered, and thereby require $\frac{1}{4}$ or $\frac{1}{4}$ more power to do the same work, or with the same power to do less work than they might do by $\frac{1}{4}$ or $\frac{1}{4}$, in case the water was delivered at or just above the water line for this purpose.

A A, boxes let in through the ship's side, and caulked just above the load water line.

B B are side pipes, jointed with the boxes, and with

C C, strong planks bolted against the sides of the pump, in order that the side pipes may be got out and in without disturbance to the pump.

D D is a stand-pipe, to be carried up to the main deck, or as high as is thought necessary, that when the seas rise above the orifices, or the ship in distress, should be under her load water line, that the water may not revert and run into the ship: and
here

here it is to be noted, that both boxes and pipes should be wholly under water, yet it will no ways interrupt the action of the pump; for whenever the water in the stand-pipe rises above the level of the water without, the pressure of the column in the stand-pipe will cause it to make its way through the side pipes; so that in this case no level will be lost, and though the pump is at rest, no water can revert down the pump, because there are the valves of both bucket and fixed box to prevent it.

The present design is adapted to be worked at the height of 22 feet by four men, who working at a moderate rate, so as to hold it an hour, will in that time deliver 20 tons. This is upon a supposition of raising the water to the usual height; but if, by the application of the maxims above described, this perpendicular is shortened to 16 or 17 feet, then will the same delivery nearly be made by three men, or proportionably more by four men, that is, as $17:22::20:26$ tons at 17 feet; but in this case, the distance of the center of the lever or brake must be lengthened from 1 foot 6 inches to 1 foot 11 inches 3, and the barrel must be lengthened 4 inches.

According as the design is drawn, viz. for a perpendicular of 22 feet by four men, they are supposed to make no more than 25 strokes per minute, moving the pump-rod $13\frac{1}{4}$ up and down at each stroke. This will be much better than to make shorter strokes and quicker, as they usually do; in this case their hands will move up and down about 4 feet 6 inches, and the same number of strokes, scope, and pressure at the hand will be sufficient for the reduced perpendicular, but then the stroke of the pump-rod will be $17\frac{1}{4}$ inches.

With respect to the mechanism, I believe it will appear sufficiently plain by the designs, which are drawn true to a scale; but it may be necessary to remark, that the working-barrel is to be of brass, and very truly bored, the bucket and fixed box of the same construction as those used in the steam-engines, and the pump-rod is to be made of the bulk represented in the figures, not by way of strength, but by way of weight; that when the brake is lifted up the pump-rod may readily descend by its own weight; and it is to be noted, that if the weight arising from the dimensions specified does not carry it down with sufficient readiness, that it is a sign the bucket is too hard leathered, or the valves too heavy.

It is to be observed, that the foot of the pump is to be let through the ceiling betwixt two of the floor timbers, and not to touch the bottom or outside planking within $2\frac{1}{2}$ inches, and that the lower end be rounded trumpet fashion. I entirely object to the pump's standing upon its lower extremity, with holes bored to let in the water.

N. B.

N. B. If the foot stands close to one or both timbers, there ought to be left 3 inches between the bottom and the planking.

In case the pump is made to the 22 feet height the stand-pipe will then become unnecessary; and therefore to allow a proper length and weight to the pump-rod it will be proper to let down the working-barrel door and box lower down in the tree. The quantity must be assigned by the convenience of coming at the door; but the working-barrel had better not be above 16 or 17 feet above the bottom, if it can be avoided.

The four men are supposed to stand one on each side the middle stem of the brake, and one on each outside of the branches, and every quarter of an hour they will find an easement by changing hands, which is done by changing places.

This pump may be worked by six men, but not so as to produce a greater quantity in proportion to four; it may also by three, but then they must change every quarter of an hour.

It may be made also to work double, in which case eight men may be employed with advantage; but as I imagine two independent pumps will be better adapted to ships use, that if one be out of order, or happen an accident, the other may be serviceable, it is for this reason I have not given a design for a double pump.

I suppose it scarce needful to say, that it would proper that a bit of the cieling should be made to lift up near the pump's foot, that a man may occasionally get in his arm to clear away any chips, sand, dirt or other matter that may happen to be drawn thither.

Austhorpe, 9th August, 1768.

J. SMEATON.

CARRON FURNACE.

The REPORT of JOHN SMEATON, Engineer, concerning the Improvements of the Blast at the furnace at *Carron*, No. 4.

HAVING maturely considered the easiest and most effectual way of altering the blast No. 4, so as to perform its business equally with No. 1, I recommend the following alterations, yet, without a total change, which is not the present object, the company will be obliged to submit to its using more water than No. 1, though, in this respect, they will find it greatly improved beyond its present state.

I would advise that the water-wheel and the three cylinders, with their respective beams, remain as they now do, as also the frame that holds the crank, but to add a fourth cylinder abreast of the other three, on the outside or furthest off from the water-wheel, as also a fourth beam abreast of the other; the fourth cylinder to be of the same size, and in all respects fitted up similar to the other three. On this occasion it will be necessary to cast a new crank with four necks, making right angles with one another, and at distances answerable to the 'four beams,' and having the same sweep as at present. I am not perfectly clear whether there may be room enough between the present outmost cylinder and the wall to place the new one, but if not, the wall must be cut away to make room for it; with respect to the beam, it is no matter if it works very near the wall. Another couple or frame must be added for the crank like the present, and like the present the fourth neck may work in the air without an outward support. The receiver or air vessel will probably want recasting, to receive a fourth air-pipe from the fourth cylinder, unless the workmen can contrive to cut a hole into it, and by proper straps to confine the additional pipe thereto.

As I observed a great deal of friction in the rods passing the collars in the top of the cylinder, and yet lost a great deal of air, I mentioned last summer a method of leathering them, as well as those of the fire-engine, in a different way, whereby they would not only be rendered air-tight, but the friction in a great measure avoided; and, that this method may be properly and successfully applied, I inclose a drawing, which method I advise to be applied not, only to the new cylinder but to the three old ones, which may be done by cutting off the present necks, and drilling holes for the bolts.

DESCRIPTION of the Collar of Leather to be applied to the Blowing-machine at Carron, No. 4.

A B represents a portion of the cylindrical rods that work through the collar of leather.

C D is a portion of the section of the great plate that covers the top of the cylinders.

E F is a section of a cylindrical piece of wood, having a cylindrical hole through the middle, through which the rod may slide freely, but with as little shake as possible, which is to be made of beech, crab-tree, yew, or some hard or tough wood that will wear well with iron.

abc abc shews the section of the leather by which the hole is made air-tight, and is like an hat with the top of the crown cut out.

G H I K G I I K is a section of a cylindrical box for holding the cylindrical piece of wood, with proper flanches, by which the box is screwed down to the cover C D, and by which the plate, of which L M is the section, is screwed down so as to hold fast.

N O is the section of a piece of leather for securing the joint betwixt the box and the cover.

It is obvious from the figure, that no part of the cylindrical rod is intended to touch the ironwork nor the leather N O, but that it is to be kept steady by the wooden cylinder, and the joint rendered air-tight by the pliable cylinder of leather *bc bc*, which, as well as the wood, are to be changed whenever they are found to fail.

The method of making those leathers is as follows :

P Q represents the section of a cylindrical iron ring, whose external diameter is equal to that of the wood C D, and whose internal diameter is about $\frac{1}{4}$ of an inch larger than the diameter of the cylindrical iron rod A B.

R S is the section of a flat round piece of leather of about $\frac{1}{4}$ of an inch thick, being of the thickest sort of leather used for the upper leathers of shoes.

T V W X

T V W X is a piece of hard wood, turned to the shape here represented, whereof the part T is of the same diameter as the cylindrical rod A B and V W, to the same diameter as the wood E F; then having cut the piece of leather to about an inch more in diameter than V W, with a mallet sticking upon the head of the piece of wood at X, the leather will be forced into the iron ring, and form the shape of an hat, and with a knife cutting off the superfluities even with the outside of the wood V W, it will then be of a size proper for use; after staying some little time, release it, and with a sharp narrow-bladed knife cut out the crown even with the inside of the cylindrical part of the leather, and by holding the blade of the knife parallel with the axis of the cylinder, it will give it the shape *abc abc*.

The leather will be rendered more compliable, if need be, by being first wet, and will keep its shape better if suffered to dry in a thin hoop, whose inside is the same as the inside of the ring P Q; if it cannot be made without puckering, it is a sign that the part T is too prominent, for even $\frac{1}{2}$ an inch of turn down will answer the purpose, duntle leather wetted is also more compliable than the common tanned.

It is to be observed, that the rods be drawfiled very smooth, and first of all worked with a mixture of soft grease and powder of black lead, and afterwards black lead simply.

It will also be of further advantage, in respect to the saving of water, to lay the water about three buckets higher upon the wheel, according to the method first proposed for No. 1.

J. SMEATON.

Austhorpe, February 11, 1769.

Answer to Queries by Mess. GRIEVE and BENSON.

Carren, July 10, 1769.

Mr. GASCOIGNE having shewn me Mr. SMEATON's letter to-day, in which there is the following query, viz.

" Mr. GRIEVE informed me, that at the rate I saw No. 4 a-going, viz. 18 cylinders per minute, that she did 30 baskets per day: query, what is her common rate of blowing.

Vol. I. A a a ing,

ing, that is, how many cylinders in common with a full head, and how many baskets is then done?"

To which I answer, that 18 cylinders per minute is the usual rate of blowing at No. 4; that she blows down from 30 to 35 charges per day; she is not now allowed to go more than 18 cylinders a minute, which is performed at the lower gate at all times, and with the upper gate when the pool is very full. Some time ago both gates were used, even then she never went more than 21 or 22 cylinders per minute, nor more than between 30 and 35 charges per day, yet I have known her drive as many as 45 charges per day; such is the uncertainty of founding on the number of charges as the basis of a calculation.

He also informed me, that No. 3 made 15 cylinders per minute with 1 gate, and 18 cylinders with both; query, how many baskets respectively?

To this I reply, that No. 3, with a full head, does make these cylinders; at this furnace we always blow with both gates, and therefore I cannot say how many charges she may run at 15 cylinders per minute; but at 18 she blows down from 25 to 29 charges per day, and if the water in the pool be 2 feet or 30 inches lower than full head, this No. 3 furnace will not drive above 15 or 16 charges per day.

Mr. SMEATON will please to advert, that a charge consists of several baskets of mine, coal; and lime-stone, which is put into the furnace when the materials are sunk in her to a certain depth; now this charge consists sometimes of more or less baskets than at other times, just as the working of the furnace requires it; and it must likewise be observed, that the quality of the materials has great influence on the driving of the furnace.

JOHN GRIFFITH.

When No. 1 blows 25 cylinders per minute, she will make 28 baskets per day.

When No. 2 blows 34 bellows per minute, she will make 20 baskets per day.

J. BENSON.

Mr.

**Mr. BENSON's Answers to Mr. SMEATON's Queries of the 11th, as far they respect
No. 1 and 2.**

Carron, July 12, 1769.

IN the first place Mr. SMEATON will please to observe, that the coals and lime-stones, used in each furnace are all of the same qualities, and nearly the same quantities; the difference is not worth notice.

Query 1st. Answer. The mines used in No. 1 and 4 are quite different qualities, so can only say what difference there is in the weights of the mine used to a charge; No. 1 charge of mine is about $\frac{1}{8}$ to $\frac{1}{4}$ heavier than No. 4; when No. 1 is running 28, and No. 4, 30 to 35 charges per day, supposing both furnaces of the same shape, but they are not, No. 1 blast is more repelled than No. 4.

Query 2d. Answer. The materials of No. 1 and 2 are much the same; the mine of No. 1 charge weighs about $\frac{1}{4}$ heavier than No. 2; this difference arises chiefly from the shapes of the furnaces, and not from the blast.

Query 3d. Answer. The quality of the iron in No. 1 may be as good when she runs 28 charges per day, as when she runs 18 and 23, provided she be working what we call clean natural mines, or mines not possessed of poisonous matters; but the quality of the iron depends upon that, and the quantity of mine used to a charge.

Query 4th. Answer. I never wrought No. 2 at 10 to 12 charges per day; but was that the case, she would take a double set of men to work her, and the iron would be so cold for want of its mother cinder, which cinder can only be produced in a blast furnace by a proper quantity of blast, it would be of no service but for pigs, and scarcely would run out of the hearth even into them.

JOHN BENSON.

**Mr. GRIEVE's Answers to Mr. SMEATON's six Queries, dated the 11th instant, as far
as they respect No. 3 and 4. B. Furnaces.**

Carron, July 12, 1769.

TO Query 1st. The coal and limestone used to a charge is much the same in all the furnaces.

No 1. carries commonly $\frac{1}{4}$ or $\frac{1}{5}$ part of more mine to a charge than No. 4. but it must be observed that the quality of the mines used at No. 1. and No. 4. are always different, and to come at the ability of each, they should be loaded with equal materials.

To Query 2d. I reckon No. 3 carries $\frac{1}{4}$ or $\frac{1}{5}$ part more mine than No. 4; but this is as uncertain as the answer to query 1st, on account they are never loaded with the same sort of mine.

To Query 5th. With the same materials, I believe, No. 1 and No. 4 will make nearly the same quality of iron, yet there may be a difference in favour of No. 1, on account of her drier situation, and her better make.

To Query 6th. This depends entirely upon the nature of the materials; No. 3, when she drives 25 to 29 charges a day, will make as good iron as when she drives only 15 or 16 charges a day, provided, in both cases, she be working what we call wholesome mines; but if the materials are endued with any pernicious qualities, every furnace will make better iron by working than fast: The reason is obvious, by driving slow the materials remain longer in the body of the furnace, and so have more time to throw out their sulphurs, or the heterogeneous matter, with which they abound, escapes by sublimation or attraction, which hard driving would carry down with and poison the iron.

JOHN GRIEVE.

EXPLANATION for the Design of the Blast Machine for the Furnace No. 2, at Carron.

AS in this machine I have the advantage of ordering the water wheel, which I judge best to be over-shot, this circumstance reduces its height so much, that, by a small enlargement of the cylinders, it can be allowed to go at such a speed as to do without geer, which however well they have answered in No. 1, where they were necessary, yet, where the same proportions in the movements can be accomplished without geer, are more properly avoided.

I have also chose, instead of making two regulator beams working a cylinder at each end, as in No. 1, to make four beams or great levers with cylinders at one end only, by this means, the strain of the crank always laying downwards, and bearing upon its
brasses

brasses the same way as the water-wheel, will work more easy and pleasant, and be less liable to get a shake, and be out of order by continuance of wear: The whole, therefore, of the motions being performed with more ease and simplicity than No. 1, I expect it to be subject to less attention and repairs, and that it will not require above $\frac{1}{4}$ of the water to work it, taken by No. 1.

There will be more timber in the framing, but as it will be nothing but common fir timber, I apprehend this will be no object, and this will be more than saved in the water-wheel and axis, the spurn-wheel, and pinion.

No. 1 is a design for the upright of the water-wheel; it is here shewn to be of 20 feet diameter, but as, on my last view at *Carron*, I understand that the wheel No. 2 lays lower than the rest, and is sometimes affected by tail water, when *Stenhouse* mill-dam is full, a circumstance I was not before apprised of; in order to avoid that, it may, perhaps, be necessary to reduce the diameter of the new wheel from 20 feet to 19 feet 6 inches; but, yet, if *Stenhouse* mill-dam never throws above 3 inches dead water upon the bottom of the present wheel, then the new wheel may be laid as low as the present wheel, because that quantity of dead water, supposing the tail water-course from the wheel be open and free, will be of no prejudice to the going of the new wheel.

The reduction of the water-wheel to 19 feet 6 inches is, again, only upon a supposition that the pond is subject to be reduced 1 foot 9 inches below head, as I saw it the 7th instant; but if it is never suffered to go above 1 foot below head, as advised in my report of this day, or, at most, 14 or 15 inches, then the water-wheel may be of its full size, though it should be obliged to be raised at the bottom from 3 to 6 inches, to sufficiently clear the tail water.

The elevation here given is supposed to be of the outward front, but as I find the tail water goes off the contrary way to what is here shewn, and will require a different kind of penstock, for which I will send a particular design when I return to *England*, it will be proper to lay a sweep to the breast of this wheel, to fit it as close as possible, but it may either embrace the wheel a quarter round, or only $\frac{1}{4}$ of the circle as is found most convenient in the execution; the two different ways are shewn according to the letters *ABC* and *ADE*.

The width of the wheel is supposed to be as great as the conduit will allow, as it will work steady like No. 1, no allowance need be made for shake.

No. 2 is a plan of the whole machine, and an elevation of one of the truss frames and beams, with a section of one of the cylinders; upon which it is only necessary to observe, that as the method of framing the truss-frames are the same as No. 1, whatever difference there is in the disposition, will be sufficiently obvious from the draught.

It is, however, to be observed, that as, for the ease of casting, I have supposed the crank to be cast in two pieces, particular notice is taken that one of the heads be set a small matter atwist, with the arms of the crank, that when the whole crank comes to a bearing in the box that couples them together, the arms of the first half of the crank may make a perfect right angle with the arms of the second, otherwise if this circumstance is not attended to, the clearance necessary to get the box entered upon the two heads, will produce a shake, that when the whole comes to a bearing, the arms of the two halves of the crank will not stand square to each other, which will produce an inequality in the blast.

The crank end of the regulator beam or lever has a piece of cast iron A, which is to be made of such a weight as to overhaul the piston, which, for the sake of lightness in this machine, is to be made of wood, or as light of iron as it can be properly cast; the pistons, however, are to be leathered, as in No. 1; the proposed use of the weight at A overhauling the piston, is to prevent the crank-rod from changing its bearings upon the crank neck, for, by always bearing downwards, it will be no matter whether the neck-collars be tight or not, so that the only collars that will be needed to be kept tight, (which they very easily may, having but little motion,) are the tops of the crank and piston rods, and the center gudgeon of the levers.

B is a provisionary flanch, which is here shewn to be mute; the opening to be about 6 inches diameter in the clear, and the use is, that in case a perfect equality in the blast should be afterwards found to be preferable to all others, as I am at present much inclined to suppose, from hence there may be made a communication to an air receiver or vessel, which will fully effect that purpose.

J. SMEATON.

Kew House, July 31, 1769.

The WATER at CARRON.

The REPORT of JOHN SMEATON, Engineer, concerning the quantity and disposition of the water at *Carron*, from a view taken thereof the 7th of July, 1769.

AS the several blast furnaces at *Carron* are of different dimensions, work upon different kinds of ore, and take different quantities thereof at a charge, the wheels take their water at different heights, and, at the time of this view, the pond from which they were supplied was so low, that the head of water upon each wheel was a good deal uncertain in the different penstocks; it is not to be expected that any very accurate conclusion can be drawn by way of comparison of the several machines, in regard to their powers of reducing the ores or mine into metal; yet, in attempting the comparison in the best way I am able, it appears to me that several matters offer themselves which seem worthy of serious attention from the Company.

Amidst the uncertainties above mentioned, it seems impossible to fix upon any absolute criterion or common measure to which they can all be reduced. The quantity of metal produced from the furnace seems improper, because the poorest ore (I must presume) takes most labour of the furnace, and yields the least iron; the different quantity of air that each machine throws into its respective furnace appears also equally unfit, because, if we are to judge by this alone, it will appear that the machine No. 4 will, with an equal supply of water, throw out more air in a minute than No. 1; and this will also hold with No. 3, and therefore we must conclude that the machine No. 1 is inferior to No. 4, and also to No. 3. A conclusion which I suppose must be rejected from all experience hitherto had, and consequently the premises from which it is drawn.

It remains therefore that the number of charges, as they do not much differ in weights, which each furnace can work off in a given time, relative to a given quantity of water, is the only handle we can at present lay hold of, and is, as I perceive, the same by which the managers and workmen reckon; and though, on the account before mentioned, it may not be very exact as common measure, yet I find the differences of the effects of the furnaces relative to a given quantity of water are so very remarkable, that though our conclusion formed from thence will be short of perfect accuracy, yet they may enable us to adopt a better distribution of the water than at present.

The distribution and effects of the water on the day of view was as follows :

		Strokes per minute.	Charges per day.	Cube feet of water expended per minute.
Table 1.	No. 1.	19	23	267
	2.	28	18	555
	4.	16½	30	780
			—	—
Total charges per day			71	with 1602 cube feet of water per minute.

N. B. At this time No. 3 was standing still.

When all the furnaces have a full head and supply of water, the number of strokes of the cylinders and bellows per minute, relative to the number of charges per day, as per information of Messrs. BENSON and GRIEVE, are in the following table ; and comparing the several heads of water and apertures that these must obtain with the present, the expence of water relative to those strokes and charges will also be as therein specified.

		Strokes per minute.	Charges per day.	Cube feet of water.
Table 2.	No. 1.	25	28	481
	2.	34	20	761
	3.	18	27	1362
	4.	18	32½	852
			—	—
			107½	3456

Now, comparing the respective numbers in the second table with those of the first, it appears, that the quantity of water expended to drive an increased number of charges, greatly exceeds the proportion in which the number of charges increase ; for taking the totals, to advance the charges from 71 to 107½, that is nearly as 2 to 3, the water must be increased from 1602 to 3456, that is more than in the proportion of 2 to 4. Again, in the furnace No. 1, to advance the charges from 23 to 28, the water must be almost doubled, and the disproportion greater or less is observable in all the rest. Mr. GRIEVE reports, that respecting the furnace No. 3, with the upper gate drawn alone, with a full head of water, it will give 15 cylinders per minute, but with both gates drawn, in which case the expenditure of water will be doubled, the number of cylinders are no more than 18 ; and as it otherwise appears that the quantity of charges relative to each furnace is almost, but not quite, proportionable to the number of cylinders, in the furnace also the disproportion between the water and the charges is as great as in any of the rest, and indeed the proportion, though in somewhat different degrees, appears from the united testimony of the machines of every construction.

Observing

Observing this disproportion, and my mind suggesting to me the use that might be made thereof, towards a better allotment of the water, I found it necessary to know whether the iron produced by the several furnaces at their low rates of working was as good as the iron produced at their higher rates of working; and from the answers I have received from Messrs. BENSON and GRIEVE, it appears that the low rates of working produces quite as good iron as the higher, and in cases of impure mine considerably better; however, it seems there are rates of working so slow, that the iron would not be put in a sufficient fusion, as would happen if No. 2 was reduced from 18 to 10 or 12 charges per day.

From a diligent comparison of the above particulars with each other, and also with the theory which they ought to conform to, if the experiments could have been made with accuracy, I have endeavoured to settle the proportions in which each furnace would work with an equal distribution of water, according to the quantity in which it was used during my observations on the day of trial, which, according to table 1, was at the rate of 1602 cube feet per minute, say 1600; by this means we shall be enabled in some measure to enter into the merits of each, as well as to elucidate some other points. Supposing then the 1600 feet equally divided amongst the whole four, each will work with 400 cube feet per minute, and their several performances may be expected as follows.

	Strokes.	Charges.	Cube feet of air per minute.
Table 3. {	No 1. 23½	27	1194
	2. 25	16	
	3. 12	18	1459
	4. 13	24	1811
Total No. of charges		85	
Ditto per table 1.		71	
Difference		14 in favour of disposition table 3.	

If we suppose 1600 feet of water divided equally amongst the three furnaces of table 1, they will each have 533 cube feet per minute; they may then be expected to move as follows:

Table 4. {	No. 1.	26	29	} 533 cube feet per minute.
	2.	27½	17½	
	4.	14½	26½	
Total number of charges		73		
Ditto per table 1st		71		
Difference		2 in favour of disposition table 4.		

N. B. This last disposition, though it advances the number of charges by two, yet as it throws more work upon No. 1 and 2 collectively, and less upon No. 4, which works single, I suppose the convenience upon the whole may be less.

The following equal disposition of the water amongst three furnaces may perhaps answer better, as it not only makes a better produce, but divides the work of the two houses more equally.

Table 5.	{	No. 1.	26	29	} 533 cube feet per minute.
		3.	$13\frac{1}{4}$	$19\frac{1}{4}$	
		4.	$14\frac{1}{2}$	$26\frac{1}{2}$	
				<hr/>	
		Total charges	-	$75\frac{3}{4}$	
		Ditto per table 1ft		$7\frac{1}{2}$	
				<hr/>	
		Difference	-	$4\frac{1}{4}$	in favour of disposition Table 5.

From the above disposition, I deduce the following probable inferences.

1st. That the number of charges does not depend wholly upon the quantity of air produced by the machines, but in a great degree upon the regularity of the blast,

2d. That the number of charges does not depend upon the velocity wherewith the air is thrown into the furnace, but rather upon the quantity of air that is made to pass regularly through the materials contained in the furnace in a given time.

3d. That this quantity so made to pass may have its limits, for too much may spoil the metal by over-heating it, and too little will not produce heat enough to give it, and keep it in the necessary state of fusion, and which limits can only be ascertained by experience.

4th. That the worst machine is capable of working a given number of charges with less expence of water than will be required to be added to the best, to advance its produce by an equal number.

6th. That the most advantageous way, when water is short, is to keep down No. 2 and 3 to as few charges as can be admitted to do their business well, in point of quality, and to divide the water, after these are served, equally betwixt No. 1 and 4; but when No. 1, so served, runs above 28 charges, or No. 4 above 30, then such overplus to be equally drawn upon 2 and 3, and so on, upon the waters mending, till they are all advanced to their highest pitch, and the contrary method upon its decline.

We will now examine the real supplies at the times of shortest water, and endeavour to ascertain the best means of using it.

From the gage of the river's water taken at the long arch it appears, that at that time it amounted to 990 cube feet per minute; but as the water was said to come down more in the day than the night, on account of stoppage of mills above, and also that sometimes by continuance of drought runs still shorter than at present, it was thought it was in the greatest scarcity on an average not more than $\frac{2}{3}$ of what we then measured.

The fire-engine at that time went from 6 to 8 strokes per minute of $5\frac{1}{2}$ feet each; but as she was frequently obliged to stop to gather steam, this with other stoppages in the 24 hours, together with the loss by shutting of valves, makes me reduce her average rate to five strokes per minute at 5 feet each.

The fire-engine will therefore raise per minute	440.
And the river <i>Carron</i> at lowest	- - 660
	<hr/>
Total	- 1100

I understand from Mr. GRIEVE that No. 3 makes good iron at 15 charges per day, and from Mr. BENSON that No. 2 will not answer at 10 or 12; but I will suppose that No. 2 will work as well at 15 charges as No. 3 does, and as they are allowed to work well at that rate, they may be supposed to do so at a somewhat a smaller rate; dividing, therefore, the 1100 feet equally amongst the four furnaces (which reduces No. 2 and 3 nearly to the rates abovementioned) we shall have, as follows:

		Strokes.		Charges.	
Table 6.	No. 1.	21	-	23.8	} 275 cubic feet per minute
	2.	22	-	14.1	
	3.	10 $\frac{1}{2}$	-	15.9	
	4.	11 $\frac{1}{2}$	-	21.2	
		Total charges	-	75	
		Ditto per table 1st	-	71	
		Difference	-	4 in favour of disposition No. 6.	

Hence it appears that in the lowest state of the river *Carron*, by disposition table 6th, there will be 4 charges per day worked by 1100 feet of water per minute more than is done by disposition table 1st by 1600.

To complete this view, I will suppose all the furnaces equally perfect as No. 1, and that they are confined to the supply of the river *Carron* alone in its lowest state, that is, 660 cube feet per minute; there will be therefore a supply of 165 feet for each machine. These 4 machines with that supply will go $17\frac{1}{2}$ cylinders each, and work $19\frac{1}{2}$ charges, in the whole 78 charges per day, that is, 7 charges more without the fire-engine than they do with it at the time that the river *Carron* supplies 990 feet of water per minute.

In these computations I reject the circumstance that No. 1 and 3 carry about $\frac{1}{12}$ more weight of ore to the furnaces at a charge than No. 2 and 4, which is much in favour of the two former; but as there appears to be several other differences of circumstances as well as those, I rather chose to take the whole in the gross from the number of charges, without dwelling on minute circumstances.

Concerning the Nose-pipes.

It is suggested in the 2d deduction, that the effect of the furnace does not depend upon the velocity wherewith the air is thrown in, but rather upon the quantity of air that is made to pass regularly through the materials contained in the furnace in a given time.

My reasons for this inference are the following: that in all cases the number of charges worked by each furnace are, when proper deductions are made for the friction of the machine, very nearly proportionable to the quantity of air thrown in by the same machine, and though it will hold equally true, that when different quantities of air pass through the same nose-pipe, the velocity will be proportionable to the quantity, and, therefore, in like manner proportionable to the number of charges; yet, as a double quantity of air applied to a double or two furnaces with an equal velocity, produces a double effect, it is most probable that a double quantity of air producing a double effect in the same furnace, is also owing simply to the double quantity of air thrown in, the double velocity being only a concomitant circumstance attending the throwing a double quantity through the same orifice; and this appears still the more probable, as within certain limits a less velocity of air as effectually converts a proportionable quantity of mine into metal as a greater. Now suppose any furnace, for instance No. 1, will do her work well at 14 cylinders per minute, in which case she is said to dispatch 18 charges with a nose-pipe of 3 inches, if the machine is made to go 28 cylinders, and drive her air through a nose-pipe of double area, viz. $4\frac{1}{4}$, she would then blow a double quantity of air, and would only require a double quantity of water; but if she

is

is made to blow 28 cylinders through the same nose-pipe of 3 inches, it will require *eight times* the quantity of water, and yet the number of charges *scarcely doubled*, and the metal itself, at the best, no better, and in some cases not so good. Hence appears not only the great advantage in point of water, of working a greater number of furnaces at low charges, rather than a smaller number at higher, but also the advantage of applying as wide a nose-pipe as can be admitted, so that the air may really enter the furnace, and not be repelled back again; and in this respect an equal blast will have very greatly the advantage over an unequal one; but I apprehend that it may be practically known when any part of the air is repelled, because when there is no sensible reverberation on the hand or face, it is evident it must enter the furnace. If, therefore, it should be found, that when No. 1 goes 25 cylinders, all the air will enter the furnace from a nose-pipe of $4\frac{1}{2}$ inches, or, for the sake of an addition of velocity to make it enter, suppose of $3\frac{3}{4}$, it will then work with 247 cube feet of air per minute, instead of 481, which, per Table 2, is requisite for the same number of cylinders through a 3 inch nose-pipe; and, consequently, if all the furnaces were equally perfect with No. 1, they would be capable, in the very lowest state of the river *Carron*, (with the present help of the fire-engine) of doing more work than they now do with a full supply of water, and without the fire-engine would do more work than they now do with it.

After all, I do not pretend to determine that things will succeed exactly in this manner. The physical nature of bodies is not to be circumscribed by geometrical reasonings, which have only quantity for their object; all I mean really to investigate is, that if the nature and conveniencies will, *upon trial*, admit of their being worked in the manner suggested, then such advantages in point of power will follow; yet I do not mean to say that the advantages will follow precisely in the quantities I have set down; this is not to be expected, unless the data on which I have been obliged to proceed could have been more accurately had: however, notwithstanding a degree of inaccuracy in the data, I presume it cannot be so great but that the reasonings thereon founded will at least shew which way the advantage lies, and thereby furnish matter for experiments, which, as they could easily be tried, and if attended with success will be of great consequence in the application of the present powers to the best advantage, I cannot but earnestly recommend the trial thereof as speedily as convenience will admit, which is the whole aim of what I have delivered.

Concerning the Improvement of the Blaft Machines.

No. 1 is now fupposed compleat, and a ftandard for the reft.

No. 2 appears at prefent to be the moft faulty, but when rebuilt according to the plan given in with this report, I fuppose will perform at leaft equal with No. 1 in making iron, and go with $\frac{1}{4}$ or $\frac{1}{5}$ lefs water.

No. 3 appears to take confiderably more water than any of the cylinder machines relative to the number of charges; what preference it has in reducing thofe charges into metal I can be no judge of. I apprehend, however, it would be confiderably improved in its prefent form if the two blow-pipes were connected by an air-chefft furnifhed with valves, and from thence to blow from one nofe-pipe. As this alteration may be eafily made it feems worth the trial; but I apprehend it will never perform quite well till it is put into the form of either No. 1 or 2.

No. 4 will, I apprehend, perform nearly with No. 1, when furnifhed with a fourth cylinder. This I fuppose, becaufe when their effects are compared when working with the fame quantity of water as per table 3, the difference is not much greater than what fhould arife from the wrong proportion of the parts of No. 4, which will be in a great meafure corrected by the addition of a fourth cylinder.

It would be a faving of water in the whole if the pond of *Carron* was never fuffered to go lower than from 6 inches to a foot below a full head, and rather than fuffer that, to draw the neceffary water from the refervoir at *Larbet*, or to reduce a number of cylinders blown at each machine, according to the proportions fuggelted in tables 3d and 6th.

Concerning the Boring Machines.

	Cube feet.
The over-shot wheel in boring a gun of 6 $\frac{1}{2}$ inches, ufed per minute	341
The cutting-machine	168
	<hr/>
Together	509
But as one cutting-mill fupplies two boring, fubtract half the cutting-mill's water	84
	<hr/>
Neat quantity expended to keep a cutting and boring machine at work continually	425

In regard to the small boring and turning mill at the side above, I find it takes 495 cube feet per minute; but as I understand it only goes when there is a full head and plenty of water, I lay it out of the consideration.

It appears then, that to keep one boring machine, with the necessary cutting, going continually, they take near $\frac{2}{3}$ of the whole produce of the river *Carron* in short water times, that is, almost as much as the fire-engine draws; and though these machines be supposed to go only 12 hours in 24, yet they will still consume as much water as will work the furnace-machine No. 1 at 22 charges per day; a destruction of power which has been very properly seen by the Company, and therefore proposed it as very desirable that those machines should be intirely silenced in short water times, and a new one erected in lieu thereof upon the tail water proceeding from all the furnaces collectively.

Now if these 2 machines require 569 cube feet per minute to work them when there is a fall of at least 20 feet, a fall of 6 feet, (which is the utmost I think can be well had for the tail-water into the tide's way) will require 1697 feet; whereas the river *Carron* does not supply half of this water in very dry seasons, and the engine water will not apply itself to this machine; notwithstanding, I can assure the Company that I can undertake to furnish a design, wherein the water can be applied in so superior a manner, in point of power, to what it is to the present machines, that the river *Carron*, at 660 cube feet per minute, upon a fall of 6 feet only, shall drive those machines as effectually as they are now driven with 509 feet upon their present head.

Kersey-House, July 31, 1769.

J. SMEATON.

RESOLUTIONS of the *Carron* Company.

AT a monthly meeting of the partners of *Carron* company, held at *Carron*, 10th of August, and following Days, 1769.

Present, • Mr. JOHN ADAMS,
Mr. CHA. GASCOYNE,
Mr. THOMAS ROEBUCK,
Mr. WM. CADELL, jun, and
Mr. JOHN CADELL.

Mr.

Mr. SMEATON's report of the 7th of July last, made in consequence of our letter, dated July 1, having been read to the meeting,

Resolved, That the said report be approved of, and that the necessary steps be taken, as soon as convenient, to make such trials and experiments of the use and distribution of the water, according to the tables contained in the said report.

Resolved, That Mr. SMEATON be requested to give the company a scheme and plan of the boring-mill mentioned in his report, as soon as it suits his conveniency.

Resolved, That the thanks of the meeting be transmitted to Mr. SMEATON, as a mark of the sense they entertain of the attention he is pleased to pay to their works.

CHA. GASCOYNE, P.

Some Remarks concerning the design for a double boring mill for cylinders and guns, to be erected upon the tail-water of the *Carron* works.

I propose the machine to be erected upon the opposite side of the tail water-course to that on which the blast furnaces stand, and in any part of the yard that upon the whole shall be thought most convenient, which depending upon a great number of circumstances that I cannot be acquainted with, must be judged of by the Company; nor is it all material to the action of the machines whether they stand as close to this water-course as they can well be disposed of, or be carried further into the yard. According to the general design No. 1, it is proposed to turn the tail water-course of these mills a quarter round, so as to proceed nearly in a parallel direction to that of the present course to *Stenhouse* mills, and to fall into the tail water-course at *Stenhouse* mills, at such point as shall be thought most convenient on account of digging, separation of lands, &c. but in case the tail water-course is made to fall into that of *Stenhouse*, above the lowest point, to which Mr. LAURIE levelled, it will be necessary to clear up so much of the old water course as shall prevent any material loss of fall between that lowest point and the falling in of the new water-course.

Mr. LAURIE makes a fall of 8 feet 5 inches from the *bottom* of the furnace tail lead, at the lower side of the bridge next below the boring-house, to the lowest point to which he

he levelled, but as the furnace tail lead will be charged with some depth of water *above its bottom*, before the tails of any of the furnace wheels will be affected thereby, we may account the whole fall, from surface to surface, to be somewhat more than he has stated. In the present design I have supposed a neat descent at the mill of 7 feet only, for this principal reason, that I observe the ordinary spring tides flow within about 3 feet of the top of *Stenhouse* mill-dam, and as the neap tides flow within 4 feet at the height of the spring tides, I have therefore laid the wheels so that they may not be interrupted daily by the tides. I propose, therefore, that an over-fall of 50 feet length in the crown be erected at or near the place where the present one now is, at *Stenhouse* mill, to be laid 3 inches lower than the height of the water in the tail water-course at the works, when the wheels there are just free of tail-water, by which means the whole water will be vented over the over-fall, without affecting the furnace wheels, when the tail-mills are all shut; the height, therefore, of the water marked in the design for the water-wheel to be of 1 foot 3 inches above the crown of the fall, will be 1 foot 3 inches below the top of the over-fall; and allowing 2 inches for the run of the water from the works to the over-fall, this crown will be 1 foot 8 inches below the highest state of the water in the tail water-course, that will not affect the furnace wheels; but in case all the water from the furnace can be pent over *Stenhouse* dam without putting them in tail water, then this over-fall will be unnecessary. The rest of the fall to Mr. LAURIE's lowest point of level will be 1 foot, or something better, for declivity between the boring-mills and the said lowest point; but if it shall appear upon further examination that the wheels can be laid lower than I have supposed, without being affected by the ordinary neap tides, then I would add so much to the fall of the mills marked in the said water-wheel design 5 feet 9 inches; keeping the crown of the fall at the same height respecting the furnace-wheels, or not exceeding 1 inch or 2 lower, and for which, if necessary, I will send a new curve for the fall, every thing else remaining the same. It is therefore the height of the neap tides at high water that determines me as to the fall to be taken at the boring-mills; and as this height will not be diminished by any cut that may be made on the loops of the river below, that circumstance may fairly be laid out of the question, there being at present more descent to *Reay's Ford* than can be taken in for the reasons abovementioned,

The power required for boring depends so much upon the circumstances of the thing to be bored, that it is a matter that cannot be reduced to any exact calculation; but this I am not in the least doubtful of, that in the very lowest state of the *Carron* water it will carry the gun-mill with two guns boring and one cutting off, which is, I apprehend, more than the three machines at present do, and that in all ordinary times the cylinder-mill requiring less power, may be worked at the same time. It will, however, be ne-

cessary that the mill-gates, &c. at the *Stenhouse* mills be kept in good repair, otherwise a quantity of water will be expended there in leakage.

The rings of the two water-wheels I have designed to be of cast iron, in order that they may act as loaded flies, and thereby preserve the motion more steady.

I have supposed all the axes to be of cast iron, with fluted heads instead of squares, to keep them from wearing off the corners, and are what I would recommend; but forged iron spindles with square ends may be made use of instead thereof, if better approved of, for reasons I don't see. I have shewn the same fluted heads upon the two ends of the water-wheel axis that are next one another, by means whereof, if an extraordinary occasion should offer, the power of both wheels can be combined so as to act on either side.

I have been in some doubt whether so large a wheel as is represented for boring the large cylinders could be cast upon that plan; if not, the same sized wheel of 78, as is represented on the main axis for guns, being applied on each side, answers to the mean motion for cylinders; and I apprehend it may be worth while to have two motions, as the wheel will bore two cylinders at once, or a cylinder may be placing on one carriage and got ready while the other is boring: as the motions stand in the plan they answer nearly to 3, 2, and 1.

If it is found convenient to have the boring-mills so much further from the furnaces that the gangways may come towards the present tail-water course, then the quarter round turn may be made in the new lead to be cut from the same to the new mills, so that the tail-water of the boring-mills will go away directly without any turn. I don't mention this as preferable to the situation in which they are shewn in the plan, but as an hint to shew the different situation in case it should happen to be more suitable to the general convenience.

N. B. A beam being supported aloft across the three gangways for the guns, with a tackle hanging from a running roller upon the beam, will take up the gun from the gun-head carriage, and put it upon either of the boring carriages. The same may be done by a crane in the middle.

The width of the new tail-water course should be a 10 feet bottom with proper slopes, but where walled 9 feet will be sufficient.

Concerning

Concerning the alteration of the present mill for cylinders and gun-heads, if the same motions are adapted thereto as are designed for the new mills, they will equally answer. But it would go with still less water if the wheels were made so much lower as to be overshot.

In its present state it would go with far less water, and do its business better, if the motion it now has for gun-heads was adapted for cylinders, and the cylinder motion (that is, of the great axis) was applied to the gun-heads; if made new it would be right to use iron rings for the sake of the weight, whether of its present size or reduced to an overshot.

JOHN SMEATON.

Austhorpe, October 15, 1770.

EXPLANATION of the Design for building a Dam for the *Carron Works* at *Duni Pace*.

THIS design is made upon a supposition that the bed of the river where it is to be built lays about 7 feet below the level of the pen required. Mr. GASCOIGN's letter of January 16, acquaints that the bed of the river is 4 feet deeper than the top of the fill of the flood gates; supposing therefore the water over that fill at dam's height to be 3 feet, the whole height of the dam's crown above the bed of the river will be 7 feet, as drawn in this design, of which the declivity of the slope surface of the dam is intended to be 5 feet; but if the height of the dam's crown should require to be either higher or lower by 1 foot, it will make no material alteration in the design; for if it is higher than 7 feet, as it is presumed that this is reckoned from the *deepest part* of the bed of the river, there is no need to increase the declivity of the slope surface of the dam between the crown and the skirt; but if it is lower than 7 feet, the slope of the dam may be diminished so much as to leave the skirt about 2 feet above the bed of the river.

It is obvious from the design that the body of the dam is intended to be of quarry rubble; and as the greatest part of what relates to it will be readily comprehended from the design, it will be sufficient to explain those things that are less obvious.

A B, No. 1 and 2, represent two courses of flags or flat stones from a foot to 3 feet square, or oblong, as they can be got, and of 4 or 5 inches thickness: those flags are proposed to form the grand stop or pen of the water: if the whole bed of the river at the place where these rows of flags are to be footed can be come at, so as to get them inserted about 1 foot below the bed of the river, it will be sufficient without any piles for footing the same upon; but if this should prove otherwise, it will be proper to drive a row of grooved sheet piling, as represented at C C, No. 1, supported by a string piece D, and that supported and trenched down upon the bearing piles D E; this piling to be carried on at least across such deep part where a proper footing for the flags cannot be come at, and the terminations secured with the projecting part of the flags so as to make nearly a water tight joint: but was it not on account of expence it would be still more eligible if this row of piling was carried quite across, and inserted into the dam's end walls.

At any rate, the first thing to be done, is to lay in so much rubble as will support the sloping flags, and fill up the downstream side of the sheet piling, so as to break the fall of the water over them, at the height of the ground line D F; while this is doing, it will be proper to go on with the sheet of plank piling at the tail of the dam G G, supported in like manner by the string piece H, and that by the bearing piles H L, and the whole is covered by a 2 inch fir plank to preserve the parts above-mentioned from the wear of the water, and which may be renewed when worn out in a course of years, without disturbing any thing upon which the solidity of the structure depends. This sheet of plank piling in all grounds that are not rocks, is indispensable; but as the use of them is not to stop the water, but to keep in the sand and other matter, if the expence of grooving the plank piles is thought material, and the ground is sufficiently uniform to admit their being drove close edge to edge, without grooving, then this part of the business may be dispensed with: by the time the tail sheet piling is compleated, the whole area betwixt C and G should be got filled with rubble, and the row of stones marked I, which are supposed to stand edgewise to the rest, are to be got into their places: in this situation the dam will be entirely safe from derangements by floods, which will go over the work without hurting it. As the work advances, the flag stones A B are to be got in gradually, the apron of earth upwards of the flags, and the rubble and upstream setting as shewn in the section.

It is to be noted that the two rows of flags are intended to break joint one upon the other, and to be scappelled so as to lay or to pack together tolerably true; the joints all the way up are to be well stuffed with fog or *live moss*, and to be bedded with the same between the two rows of flags, this will prevent the earth from being forced through the joints

joints by the pressure of the water, and will render the whole perfectly water tight if properly attended to; the earth itself being guarded by the rubble and setting above it.

While the dam is raising, there is no doubt but that the speats going over it will scoop out the ground below the tail sheeting, so as to become 2 or 3 feet deeper than the natural bed of the river; when this happens the whole must be filled up with whin stones, or, what is best, large whin stones split into three or four pieces by powder, which will enable the angular fragments to stick together better than the whole round stones; and if any derangement happens here by speats, which is the likeliest place to happen, it must be attended to, and supplied till the water makes its exit from the tail sheeting by a regular declining current.

I think it not only unnecessary, but impracticable, to give directions about the building of the dam's end walls, as I cannot determine the situation of the body of the dam respecting the land on each side from any thing that is before me, and the method of returning the ends of the walls into the land, shewn for the dam at *Larbet*, will be sufficient guidance here; I have only to remark, that it will be proper to make those walls, for some space on each side of the crown of the dam, higher than any flood is known to rise, and that the back of these walls where the ground is disturbed or new made, must be well covered or even set with heavy rubble, in case the flood water is liable to get behind them from the adjacent haughs; for want of this precaution, I have in more instances than one known the river to make itself a new course round the outward end of the dam.

It will also be proper to make the crown of the dam about 3 inches higher at the ends than the middle, and especially towards that end where the water is disposed to act the strongest, when the crown does not make a line right across the river, which is not always proper.

Table shewing the expenditure of water, &c. in the furnaces at Carron, inclosed in Mr. SMEDON's letter to Carron Company of the 23d of July, 1776, in answer to theirs of the 14th ditto.

Number of the furnace.	Tons per Day expended by each furnace.	Cube feet of air protruded per minute.	Velocity of the protruded air in miles per minute.	Proportional effect produced.	Power required in proportion to the effect produced by No. 2.	Excess of power used more than in proportion to No. 2.
					Tons per day.	Tons per day.
1	11774	1288.7	8.838	100.672	10964	810
2	15760	1673.7	9.298	144.711	15760	
3	17630	1344.2	8.117	88.575	9647	7983
4	24972	1301.5	8.926	89.585	9757	15215
	70136				46128	24008

DIRECTIONS and Observations concerning the clay-mill, to be built upon the tail-race at Carron.

THE water-wheel, its conduits, and gate, to be in all respects the same as those of the boring-mill, except that the rings need not be of iron, observing, that in order to preserve the same head of water over the crown of the fall, that the whole be laid a few inches lower, in order to allow for the run of the water from the yard of the works to the place of the clay-mill.

I suppose the rollers themselves to be nearly the same as those now used, and to be cast upon wrought iron spindles or gudgeons: the principal difference here proposed, besides that of a very different proportion between the turns of the water-wheel and the rolls, is the addition of a fly to each roll, a larger to the driving roll, and a less to the roll driven; those are intended to keep the motion more uniform and steady, and so as not to affect the gear that drives them by the little inequalities in the passage of the clay.

These rolls are intended to go about 50 turns per minute, which, as it is considerably quicker than the present, it would greatly tend to make the work go perfectly smooth and pleasant, if they were but 18 inches instead of 2 feet length, and yet they by their greater velocity will dispatch more work.

The

The work is so placed that if stampers are desired, they may be applied for beating the clay, so as to prepare it for the rolls; but if the grinding it to a fine tough paste would be of use, for this purpose nothing would equal the runners on the edge, such as are used for oil and gunpowder mills: this would perform the whole operation from first to last, but would not reduce the clay to the consistence that the rolls do, so speedily as the rolls. A work of this kind might afterwards, if found occasion, be added to the other end of the axis, or in its present form it is capable of having a boring apparatus, or even a forge hammer applied to it if thought proper; for this reason, I would advise to make the building roomy, (of which I suppose the water-wheel to stand crossways in the center) or to leave room on each side for building. I apprehend the wheel will stand best crossways upon the present lead or leet, so that the building will range along-side thereof. In this case, the tail-water must be turned with a quarter round, the more gentle the better, but if need be, may be turned almost in its own breadth.

This water-wheel will drive two sets of rollers at once, at each end, or other equivalent works, and for one pair of rolls will go with so little water, that I believe you will scarcely find the corn-mill the worse.

J. SMEATON.

: *Austhorpe*, Feb. 21, 1777.

The REPORT of JOHN SMEATON, Engineer, concerning the quantity, regulation, and distribution of the water for working the Blast Machine for the four furnaces at *Carron* in dry seasons, together with the improvements that may be made therein, so far as regards the power of water to be employed.

IN order to answer the above purposes, I shall not only found myself upon the observations I made myself upon my view thereof in October 1776, but also upon such deductions as may be made from a thorough revifal of all the observations I have formerly made, or that have been communicated to me, of the state of these machines, by the Company at different periods; and the several computations thereon having in general been performed when I was from home, and thereby not having the opportunity of recourse to my former papers, they have been drawn up in different terms, and with different views of the subject; and also observing, in the course of my last view, some particularities which could not be so noticed when the measures were sent me, which would materially affect the calculation of the quantity of water expended, I have in the following table corrected the same, and reduced the whole to the same standard.

Table showing a comparative view, of the several Blast machines as used at *Corran*, at different periods, from the year 1769 to the year 1776 inclusive.

	No.	Diameter of nose- pipe.	Number of cy- linders.	Cube feet of air per mi- nute.	Velocity of air per se- cond.	Tons of water expended per 24 hours.
1769, working with short water,	1	3	19	1066	361½	10680
" " " " " "	4	2½	15.3	1820	582	31200
			Sum	2886	1164½	41880
			Mean	1443	582	
Ditto, with full blast,	1	3	25	1403	475½	19240
" " " " " "	4	2½	18	2258	945	34080
			Sum	3661	1420½	53320
			Mean	1830	710	
1773, February, with full blast,	1	2½	20	1122	547	
" " " " " "	2	2½	18	1255	557	
" " " " " "	3	2½	17½	1237	747	
" " " " " "	4	2½	10	1183	577	
			Sum	4797	2428	
			Mean	1199	607	
1776, July, with full blast,	1	2½	23	1289	778	15215
" " " " " "	2	2½	24	1674	818	15506
" " " " " "	3	2½	19	1343	691	18210
" " " " " "	4	2½	11	1302	785	25669
			Sum	5608	3072	74630
			Mean	1402	768	
Ditto, on view in October, with full blast,	1	2½	23	1571	947	16502
" " " " " "	2	2½	24½	1708	835	16047
" " " " " "	3	2½	19	1343	691	15732
" " " " " "	4	2½	12½	1459	881	17769
			Sum	6081	3354	66050
			Mean	1520	838	

From the above table it will evidently appear, that the machines, when worked with a full blast, have taken less and less water, ever since the first view in 1769. It also appears, that the quantity and velocity of the air does not observe any regular proportion to the quantity of water expended: but it appears in general that the less quantity of air is discharged from any given machine, and the less its velocity, and the less water it will take to work it; this also is obvious from what occurs every day, that more water produces more blast in the same machine, and the contrary.

A state of the works in February, 1773, I received from the Company, with this observation: "From our present experience of the matter, the number of strokes per minute, quoted in the annexed table, throws the air into each furnace with a degree of velocity sufficient to keep the hearths open, and to work each machine with due steadiness and regularity." Now from hence it appears, in particular, (see the preceding table, 1773,) that the quantity of air discharged, as well as the velocity where-with it was projected, was remarkably near the same in all the four machines, the mean quantity being 1199 cube feet per minute, and the mean velocity 607 feet per second, on supposition (as in all the rest) of its being discharged with an equal velocity; and as, at this season of the year, I can apprehend no scarcity of water, I must suppose the furnace then working with full blast and effect: and, as I am furthermore told, in the Company's letter of the 2d of March, that "for some years past we have fallen into the method of making the iron at the blast furnaces into pigs proper for remelting in the reverberatory furnace, for the purpose of working up our gun-heads and runners, which practice requires less velocity of blast than when we cast the guns immediately from the blast furnaces, and also admits of more regularity in the whole process; so that perhaps we can now manage with less water than it was thought we could have done in 1769 or 1773." I say, these things considered, we may ground ourselves here, that if 1200 cube feet of air is thrown into each furnace per minute, and with a velocity of from 5 to 600 feet per second, we shall certainly have sufficient blast to keep all regularly going in times of scarcity of water. I am therein also informed, that many experiments having been made in consequence of my report of 1769, "from all which we can clearly collect, that a nose-pipe for our purpose should not be less than $2\frac{1}{4}$ inches, nor more than $2\frac{3}{4}$ inches." Suppose then that the nose-pipe to be settled at a mean between them, viz. $2\frac{1}{2}$, it is not to be doubted but a little less water upon the wheel when the furnace is new, and a little more when it is worn wider, will equally answer the end as a variation of the nose-pipe, as has been remarked by the workmen as necessary: 1200 cube feet of air per minute driven through this nose-pipe will produce a velocity of 532 feet per second; and that this will be fully sufficient to keep all regularly going, though perhaps not producing the greatest quantity of metal, is evident.

dent from the state of the furnace No. 1 in 1769 and 1773. The nose-pipe being now proposed the same in all, viz $2\frac{1}{2}$ 1200 cube feet of air will be discharged per minute when the different machines go respectively as follows:

No. 1, $21\frac{10}{100}$ cylinders.

No. 2, $17\frac{20}{100}$

No. 3, $16\frac{07}{100}$

No. 3, $10\frac{10}{100}$

But as fractions may be inconvenient to the workmen, I will suppose that in short water times the several machines are regulated to the number of cylinders, as in the following table; and then the quantity of water that may be expected to be expended, proportionable to what I found in October, 1776, is contained in the four last columns of the following table:

A Table shewing the expence of water according to the regulation proposed for short water seasons, and according to different states of improvement of the machines.

No.	Cylinders per mi- nute.	Cube feet of air per mi- nute.	Velocity of air per se- cond.	Tons of water con- sumed per day, as per Oct. 1776.	Expence of water No. 3 and 4 im- proved.	Expence of water of all improved to a 23 feet fall.	Expence of water of all improved to a 24 feet fall.
1	22	1234	547	12966	12966	12312	11800
2	18	1255	556	11789	11789	10251	9824
3	17	1202	533	14076	12240	12240	11730
4	11	1301	577	15852	12312	12312	11800
				54683	49307	47115	45154
1	2	3	4	5	6	7	8

By the first table it appears, that the blast-machines, as they were working in October, 1776, were consuming at the rate of 66,000 tons per 24 hours; but by the disposition and distribution according to this last table, without any correction or alteration of the machines themselves, that quantity would be reduced to about 54,700 tons; and as it appears that the principal defects of No. 3 and 4 arise from their not taking their water so high upon their respective wheels as No. 1 does, in case these two were altered so as that the top of their upper gates should be 23 feet above the bottom of their respective wheels, then the four furnaces may be expected to work with the quantity exhibited in the 6th column, viz. about 49,300 tons per day.

If all the four furnaces were furnished with upper gates, and No. 2 wheel made larger, so as all to take the water at the same height, viz. 23 feet above their bottoms, then they may be expected to work according to column 7, that is, 47,100 tons per day, and if they were all made to take the water 24 feet above their bottoms, then they would work as per column 8, that is, with 43,100 tons per day.

As No. 3 is proposed to have an high gate, and the wheel of No. 4 to be rebuilt, and as I suppose both will be done this summer during the season of scarcity, it appears that no other provision will be wanted for the approaching season than per column 6, that is, 49,300 tons per day, because, if one of the furnaces is laid off in order to be reformed, there will be a full sufficiency of water for the other three; for it is ascertained that the river *Carron* in its lowest state affords 660 cube feet per minute, amounting to 26,400 tons per day, so that a supply of 22,900 tons per day is the utmost that can be wanted to keep all going; and this quantity can be raised by the fire-engine in its present state at the average rate of $6\frac{1}{2}$ strokes per minute, which as she may very well perform, it seems advisable not to embarrass the progress of the other business by rebuilding of the engine this season, but to give her a good overhaul to render her performance secure*.

It will now be proper to enquire what is to be expected from the home reservoirs, made and making, towards supplying the 22,900 tons per day, above stated as the deficiency of *Carron* in dry seasons; and I suppose the dam-head of *Larbert* is to be advanced one foot higher, and all the banks raised in proportion, so as to pen the water in the furnace pool and bog reservoir to 27 feet above the bottom of the furnace-wheels; these reservoirs are stated altogether at 36 *Scots* acres; and as each *Scots* acre upon 1 foot in depth contains 1521 tons, the 36 acres will contain 54,756 tons, and upon 3 feet depth (supposing the same surface at a medium) will be contained 164,268 tons, which, divided by 22,900, gives 7 $\frac{1}{3}$ days.

Now when 3 feet is drawn off from 27 feet, there will remain 24 feet, which will reduce the head upon the gates at 23 feet to 1 foot; and as this is as low an head as the water can properly act upon the wheels, it will then be time to open the lower gates to draw off the remainder. As the water will there act to a considerable disadvantage, it will be ineligible to use the engine, but when the furnace-wheels take their water from their upper gates; whatever, therefore, is drawn out of the furnace-pool below the 24 feet, must be replaced again before the engine-water can produce the proper effect upon the wheel;

* By the way, the greatest defect of the present engine is the not having a sufficiency of steam; and for this reason, the speediest remedy would be to cast and set up a new 10 feet boiler in the manner of those at *Cronstadt*, which may be placed so as to serve the new engine when erected without a removal.

and.

and as this will create a pause or stop of the whole, it will therefore be proper that it be as short as possible; for this reason it would be proper to have a stop-sluiçe upon the lead in the narrow part east of Mr. Low's house, to shut down when the surface is reduced to 24 feet, so that the *Carron* may constantly pay its tribute by cascading over the said stop, and then the furnace pool only, properly speaking, with the bog reservoir, will be emptied together below the 24 feet. Now suppose that from hence 2 feet more is drawn, which will nearly empty the bog reservoir, if the wheels take this water at 21 feet above the bottom, then they will expend by these lower gates, to produce the same effect as before, at the rate of 55,200 tons per day, from which deducting 26,400, the supply of *Carron*, there will want 28,800 from the reservoirs. I must here observe, that the quantity that we can in reality draw off, will be only from the bog reservoir, for what is drawn from the furnace-pool, will be again supplied from some recourse above the 24 feet, in order to fill it to the level of 24 feet in common with the lead and *Lar-bett* dam, because what is reserved in the dam of *Duni Pace*, or elsewhere, in order to fill it, might, if not so wanted, have been discharged at the upper gates*. Two feet then upon 24 acres is 73,000 tons, which divided by 28,800 gives $2\frac{1}{8}$ days, and this, with $7\frac{1}{8}$ from the first 3 feet over all, makes in the whole $9\frac{1}{8}$ days water, a treasury very essential to prevent frequent stoppages, and those of short duration, but no ways adequate to the purpose of going through a long drought, which generally happens once in a summer.

We will now see how the account will stand, on supposition that the high gates are all fixed at 24 feet above the bottom of the furnace-wheels, instead of 23 feet before supposed, all the rest remaining as before stated. Now as only 2 feet can be drawn off from the whole 36 acres, they will contain 109,512 tons; and on supposition that the effect is greater from a fall of 24 feet than upon a fall of 23 feet, in the proportion 24 to 23, then the quantity of water before specified to be wanted at the high gates, viz. 49,300 tons, will be less by $\frac{1}{11}$ part, viz. 47,200, from which taking 26,400, the supply of *Carron*, there will remain 20,800 to be supplied from the reservoirs; and then 109,512 tons, the content of the uppermost 2 feet, divided by 20,800, gives $5\frac{1}{8}$ days. Again, we shall now have 24 acres upon 3 feet deep, that is, 109,512 tons in the content, and the lower gates being supposed fixed at 21 feet as before, we shall have the same divisor, viz. 28,800, which gives us $3\frac{1}{8}$ days, and which added to the former make $9\frac{1}{8}$ days; hence it appears, that this latter proportion of 24 feet height of top gates does not make so much of the reservoirs as of the former 23 feet height; but this regards only the

* The communication-stop between the bog reservoir and furnace pool before such filling must shut in, so that when the furnace pool is filled, the bog reservoir may remain empty.

~~bog~~ reservoirs, whereas all water treasured up above the level of these reservoirs will doubtless have an effect in proportion to the fall from the gate.

This enquiry, however, leads us once more to see how very inefficacious reservoirs are likely to be when applied to a long-continued drought; and there is nothing so likely to prove a sheet-anchor as a plain, simple, well-constructed, powerful fire-engine, which when it does nothing will confute nothing, and being plain and strong, will be always in condition to work when needed, and the several parts to be easily inspected, so as to see whether they are or are not in working order.

From the above comparison of fixing the height of the highest gates at 23 or 24 feet, they are so nearly alike that the difference may well give way to convenience; and in this respect, unless that steps have already been taken in the works of *Carron* to the contrary, it would seem to me that the convenience would be in favour of the 23 feet; for, in the first place, it is indifferent to the engine, because she will draw at 23 feet so much water more than at 24 as the wheels will want to use. 2dly. Having been informed that the working of the forges is become so material an object, that it will be even worth while to assist them with engine-water, it will follow that it will be worth while to assist them with what will be equivalent to it.

Now on a former occasion I have laid it down, that a properly constructed engine of a 72 inch cylinder will, at 26 feet high, raise 56,000 tons per day; and supposing all the four furnaces reformed and regulated, so as to use according to column 7 of the last table, viz. 47,100 tons per day, *Carron* furnishing 26,400, there will be only wanted 20,700 tons of engine-water to them, the remainder 35,300 tons to be thrown into the forge-pool: now if the upper gates are fixed at 23 feet, they at once take off as much water from the reservoirs as will keep the furnaces going above seven days, whereas the whole of the remainder will only keep them going about $2\frac{1}{2}$ days more; and if engine-water is to be raised for the forges, why not let off the 2 feet remaining in the bog reservoir into the furnace pools, and begin to work the engine $2\frac{1}{2}$ days sooner; for this will serve instead of so much engine water to the forges, and then all perplexities will be avoided with respect to the use of different gates, as well as all attentions necessary to keep a quantity of water to refill the furnace-pool up to a level to work the upper gates, and also the necessity of a stop upon the lead avoided, as well as every attention to the use of it, so that the whole will be reduced to this simple point, that whenever the upper reservoirs are exhausted, and the lower ones reduced to 24 feet above the bottom of the wheels, then the engine begins to work, and continues till the water mends.

One thing however must be very carefully attended to during the working of the engine, and that is, as it only circulates the water, without increasing its real quantity, that care must be taken when the engine is working not to allow the boring-mills more water than is coming down into the furnace pool from *Carron*; and at the same time, during the working of the engine, that all the water drawn by the engine, and delivered into the pools, be regularly discharged by the furnace and forge wheels, *together with the supply of Carron*; for if less is let down than the engine draws, it will not only deprive the boring-mills of *Carron's* supply, (which in those cases is *the whole they can be allowed*;) but *Stenhouse* dam being reduced, the engine will want water to draw; again, if more water is let down than is drawn by the engine, and *Carron's* supply together, then the surplus quantity, after *Stenhouse* dam is full, will either run over the dam, or be spent at the boring-mills; but either way the water will be lost to the furnace-pools, which will thereby be reduced without a possibility of raising them, otherwise then by stopping the boring-mills, and letting down no more water than what the engine will draw, and then the pools will rise by the continual influx of *Carron*. These matters, so very necessary to be regulated, will, I apprehend, be done by strictly observing the following rules, a proper person being appointed to see to the observance of them:

When the furnace-pools are reduced to 24 feet, let the boring-mills be stopped, either altogether, or at nights, but so long, and at such intervals, as to suffer no water to go over *Stenhouse* dam, drawing at the same time as much water at the furnaces and forges as will supply the engine; by this treatment, the furnace-pools will gradually rise to 25 feet by the continual influx of *Carron*, which in this case they should not exceed.

When you find it exceeding that height, allow a little more water to the forges, and before it begins to run over *Stenhouse* dam, let the boring-mills draw so much as to keep it under, but not materially reduce it; by this means the boring-mills can never have more than *Carron* affords, nor the engine less than its proper quantity, nor yet the forges more than the surplusage*.

The only present difficulty is *Stenhouse* dam being leaky, and thereby letting a considerable part of *Carron's* supply escape, that should work the boring mills; but having a lighter or punt upon the dam, if fine earth is scattered over the whole surface of the slope, for 30 or 40 yards above the dam, or so far up till you come at the natural bot-

* Perhaps the best husbandry of all, of the reservoir water, instead of throwing the lowest 2 feet of the bog water immediately into the furnace-pools, will be to let it out gradually there into in such quantity, as being expended at the forges, it will, together with *Carron's* supply, fully work the boring-mills.

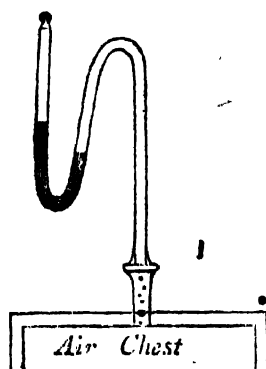
tom, and this being stirred and puddled with cow-rakes, by some pairs of this kind of three or four men for a couple of days, I doubt not but that it may be rendered sufficiently tight for the exigencies of the present year; but if you think not, if you will be preparing a quantity of stone and piling, such as was directed to be used at *Dunipace*, I will settle the particular plan for it immediately at my return from the *Derwentwater* spring receipt, which I apprehend will be about the middle of May.

The most pressing thing for this year's service is to make the alterations at No. 3, and new wheel conformable to the above, 23 feet high, for No. 4; but if made 24 feet, as formerly proposed, then all the upper gates must be made conformable, and it will be advisable to have low gates about 3 feet below the other.

When No. 3 stands still, it will be worth while to get out and rebore the cylinder that is taper, as a considerable loss of power appears to be there; and when No. 2 is stopped, it will be proper to restore the original conveyance pipes, as not only the straightness of the pipes of 7 inches, since supplied, but the driving the air through a box, when it is unconfined, to a particular direction, is, as I have experienced, a considerable loss of power. The best thing that can be done with No. 2 wheel, will be to clear it of the present buckets and shrouds, to mortice the rings for 16 studs in each, and upon those apply new rings, which, on account of being supported in 16 points instead of 8, need not be above half the scantling of the others; then cloathing these new rings with new shrouds and buckets, it may be made the same size as No. 4, the axis and crank being raised on chocks, and the crank rods shortened, leaving all the rest, inside the house, standing as at present. The water penstock must also be raised, but if made 24 feet high, should have a lower gate like the rest, and then it must be bucketed the contrary way, and have a penstock of a different kind to throw the water back, in which however near 6 inches of perpendicular will be lost; so that to draw down the pool to 24 feet, leaving 1 foot head upon the penstock, (the over-shot wheels to go the reverse way) cannot be more than $23\frac{1}{2}$ feet high.

In regulating the nose-pipes, I would advise their being brought to a clear regular surface inside, to some distance back from their very nose; and if those that are too small are bored to the gage of 2 $\frac{1}{2}$ inches, so as to leave the nose part a cylinder, I have experienced it in water to throw out a more clean and less scattered column. An attention to this, and also to keep the tuies as narrow as possible, so as just to receive the column and no more, I am convinced of it, will be found very beneficial in regard to the saving of power, or rather to make the very most of the power stipulated.

The best practical way of keeping the machines to the number of cylinders specified in the latter table, will be to furnish each furnace-keeper with a minute glass, such as are used by the shipping for the log; they must, however, be ordered on purpose to be an *exact minute*, because those made for sea are generally some seconds short, for reasons given by mariners. I have now a couple by me, which I got made in *Wapping*, for experiments, in a better manner than common, instead of sand, being furnished with granulated lead, and are very exact: but after all, unless the leathering of the pistons could always be kept equally tight, an equal number of cylinders will not always give an equal quantity of blast; but if when the leathers are in their best state, the furnaces



were furnished with a gage, consisting of a glass tube, fixed with cement to a bored brass stopple, as per margin, with a little quick-silver, this applied to a hole in any part of the air-chest, or general conveyance pipe, by observing the height that the quick-silver rises in one leg above the other, as much water applied to the wheel as will raise the gage to the difference experienced when all was tight, will not only in all states of the leathers reduce the machine to the same degree of blast, but discover when the leathers are defective, because then it will require more cylinders to keep the same difference of gage. These gages need only to be applied occasionally, when any deficiency is apprehended, and 1 or 2 may serve the 4 furnaces. If the top of the tube, which is properly to be open, has a bit of porous cane by way of peg, it will not only prevent the quicksilver scattering out, but prevent its vibrating so much by the inequality of the blast.

J. SMEATON.

Austhorpe, April 6, 1777.

P. S. I don't find I have given an answer to that letter which transmitted to me a sketch for the new furnace No. 5 for my approbation, being upon the construction of No. 2, only the water-wheel placed between the four cylinders, that is, a pair on each side, to which, if you find it more convenient in point of situation, I see no objection, or, if otherwise, no preference. It would be better with respect to the necessary speed of the water-wheel, if the cylinders were not quite so large as No. 2, viz. about 4 feet 3 inches; but as I apprehend you have already a set of models for the bottoms and air-chests ready made, by which No. 2 were cut, it will answer nearly the same end if you somewhat shorten the stroke, that is, not to exceed 4 feet. The wheel should be over-shot, and the same height as No. 4 is to be made, and No. 2 to be raised; but by all means let the air-chest be continued to join cross the separation of the two sets of machinery,

chinery, and the blast-pipe go out from the middle in the most direct manner to the tuiie, and to taper from the size originally proposed for No. 2, from the air-chest to the nose-pipe.

In considering further upon the proposition contained in the note annexed to page 8, it appears still more advantageous, if you were to keep part of the water in *Dunipace* reservoir to apply in the same manner; for by this means the boring-mills need never be short of water, nor yet any reservoir water misapplied on supposition of the forges being supplied with engine-water, or what is equivalent, and by reserving thus a sufficient part of the reservoir water, it will even answer to the leakage of *Stenhouse* dam, suppose you cannot get it tight in the way I have mentioned.

Keswick, April 10, 1777.

J. SMEATON.

DESCRIPTION of the Apparatus for putting in motion, and discharging any of the particular motions for boring the Gasconades at *Carron*.

Fig. 1. The dotted square *a b c d* represents the square end of the axis of the water wheel, or any of the side motions driven by toothed wheels therefrom as usual, and whether this is a plain square or citadel head, is here immaterial. To this square end is firmly attached an arm *A B*, which spreading both ways *C D*, and applying itself to the angle of the square, this, by means of a similar piece *E F G*, and a couple of bolts, the arm is brought on perfectly firm and solid, and will therefore continually revolve with the axis. At *A* is a mortoise through the arm 3 inches broad, and about $1\frac{1}{4}$ wide, capable of admitting a piece of iron faced with steel, and hardened, shaped somewhat like a blunt plane iron, but $\frac{3}{4}$ inch thickness, so as to fill up exactly half the mortoise, and consequently its working or steel face will be in the direction of the radius; the other half of the mortoise is occupied by iron wedges for fixing it: upon this arm may be supposed to be imbossed, but in reality cast along with it in the same piece a projecting part *B e f g b* before the plane *C D*, and also before *E F G*, being attached to the former, but detached from the latter, which projecting piece terminates forward in the ring *i k l m*, which forms a socket *H*, also coacentreal with the axis, and firmly connected therewith, which being fully understood, the rest will be easily comprehended.

Fig. 2.

Fig. 2. The square $abcd$ represents the square of a detached axis; the dotted circle ef represents the size of a gudgeon, which is adapted to the socket H in the former figure: C D are two projecting arms, that, with the axis and gudgeon, form a +, as will be readily understood from fig. 3, which represents a part of the plan of the detached axis, and wherein the same letters refer to the same parts as fig. 2. The center of the cross C D is pierced lengthways, with a smooth hole capable of receiving an inch and $\frac{1}{2}$ bolt, upon which, as a center is hung in fig. 2, the arm E F G H I K L, which in like manner contains a mortise at F of equal size and distance from the center, as the former one at A, proposed to hold in like manner a steeled iron tooth or kamm, like the former each made to project about an inch from their respective arms, and the steeled faces being contrary ways, they will meet one another with their flat faces; and it being supposed that the gudgeon ef being introduced into the socket H, fig. 1, that when the two kamms are engaged, the detached axis will be made to turn along with the original one whose square is $abcd$, but not otherwise; this will now be made more plain by

Fig. 4, wherein M is a part of the square of the original axis, N the road, O the square head seen upon the angle, as at $abcd$, fig. 1, H the gudgeon of the detached axis, P the bolt hole through the arm fig. 2 and +, Q the main body of the detached axis, R the road (not to confine it while turning the gun, but to support it when the gun is taken away), and S the square socket, that receives the square at the breach of the gun, by which it is turned round; the two arms in this figure being marked with the respective letters, as the correspondent ones fig. 1 and 2, will receive a sufficient explanation, especially when it is observed further that T is a stud cast upon that arm, which is acted upon by V, a strong spring sufficient to give the arm E F G a constant tendency to go towards the arm A B, and no in dotted lines is a staple to stop the stud and spring from rising too far, and from carrying the arm beyond its due position.

Now pq represents the kamm of the arm F G, and rs representing the kamm of the arm A B, which overlaying one another, the arm F G will necessarily be compelled to go round with the arm A B so long as they remain in this position; but to disengage it, the outlaying part of the arm E F meeting in a certain part of its revolution with an inclined plane (of wood faced with a plate of iron) that can at pleasure be interposed, this plane or wedge by acting upon the outlayer so as to separate the two arms, the kamms will be released from each other, and the outlayer, resting upon a projecting part of the wedge, will remain at rest, the other arm continuing its revolutions. The gun is then to be removed as at present, and when another is adapted to the square at S, there is nothing to do but to draw away the inclined plane or wedge; the spring throws

out the arm F G so as to form a right angle with the axis, and the next time the kamm *r s* meets the kamm *p q* it will quietly lay hold of it, and take it along with it, and so continue till discharged as before.

N. B. It is necessary that the edges of the kamms at the leaving each other should be parallel; for this reason they must not be square, but inclined according to the line *r t*; nor must the edges be quite sharp, but a little rounded; and as the continual chafing of the guns may wear the socket S faster than might be convenient, this socket may be cast with a citadel head large enough to inclose a piece with a common square within it. If the strength of the spring is not found sufficient to keep the arms together when in full strain, it is only making the kamms a little proud at the leaving edges, so that being a little matter out of parallel with the axis, they may be made so as to draw themselves together.

EXPLANATION of the Apparatus for holding and pushing forward the boring bars for the carronades without a carriage.

A B C D is the section of a square socket of cast iron, 5 inches square and 2 feet long, which is to be firmly bolted down upon a proper blocking of wood.

E F is a square of iron of the same size, and 2 feet 2 inches long, which must be fitted to the former with some degree of curiosity, so as to slide easily, and with as little shake as may be; this solid piece is to have a tapering square hole at each end, proper to receive as a socket the square of the boring-bar. This would in reality only be needed at one end for fixing the bar G G; but as it may be subject to wear, the lasting will be doubled by having a similar socket at each end.

At the opposite end of the solid piece, the piece H is inlaid for receiving the point of the screw I K, by which the solid piece and bar are to be forced forwards. L M N is a lever of wood, footed at bottom in two strong staples O P, one on each side, the lever L firmly bolted and supported by the solid blocking.

Q is a brass or a wrought iron box for the screw, hung upon trunnions as *q*, so as to give liberty to the threads of the box closely to fit and embrace the screw, notwithstanding the different position of the lever L M N.

N R is a bar of iron, by which the top of the main lever is connected with a secondary one, whose center of motion is supposed to be at S, and which going upwards beyond the limits of the paper, is represented to a smaller scale *s r t*, where there is attached a single block with an 8 or 9 inch light sheave, and a rope of about 2 inches circumference being reeved, as shewn and passing over the fixed pulley *v*, the weight W will force the point of the screw against the piece H with any degree of force required; and as I don't expect the great lever to work kindly, when more than 1 inch out of perpendicular at the height of the screw, this will give π leave to act by the weight through a space of about 2 inches, when the person attending setting forwards the screw by means of the fixed bar T X, brings up the lever and weight into its original position, and so on, till the bore is carried on to its proper length. The apparatus, in the proportion here designed, will admit of a chase of near 30 inches length, which, I apprehend, will be fully sufficient for your 24 pounders.

N. B. I am told, that a bit, whose cutting edges are brought to a proud edge by being filed to an hollow, as is shewn at *x y*, is marvellously good for boring holes in cast iron; but in this case the two edges cannot be brought into one, but the obtuse angled edge, formed by the thickness of the metal of the bit, joins the two cutting edges crossways, and forces itself forwards by being near the center, but requires a considerable pressure. I am told that 800 lb. weight will be required to bore an inch hole; and though these hollow edged bits are not so well adapted to continuance of grinding as plain ones, yet make full amends by their much less frequently wanting sharpening. How far this kind of bit may be adapted to gun boring, I leave to your trial.

Ausborpe, January 9, 1779.

J. SMEATON.



EXPLANATION of the Sketch, shewing the manner of applying the inclined plane for releasing the work of the discharging apparatus for the carronades.

Fig. 2 shews the same face of the work as is shewn in fig. 2 of the design for the discharging apparatus sent before, wherein E F G is the discharging arm, and V W is an upright piece of wood capable of sliding up and down, but in no other direction, and the same letters denote the same thing in the side view thereof, fig. 1. to which is attached or made out of the same solid X Y Z, the inclined plane or wedge. In the present

present position of it, it is in a posture for acting upon the discharging arm, and is kept up by means of the catch *m n* dropping into a notch under the piece of iron at *O*, when the arm *E* comes into the position *e*; it then begins to touch upon the inclined face *X Y*, and going forwards, by degrees gets discharged before it comes to the position *p*, which shews it discharged and resting upon the pin *q*, where it remains till the gun is shifted, and the rotation is wanted to be commenced; then the catch *m n* is drawn back by a cord, which lets the piece *V W* drop, till the line *X e* goes down to the line *q r*, viz. about $16\frac{1}{2}$ inches, which entirely clears the discharging arm, and then its own spring brings it into its working position, where the next time the revolving arm meets it, takes it along with it, and the motion will be continued till the piece *V W* is drawn up again by a cord, lever, or other equivalent contrivance, till it is supported by the catch *m n*, when at the first meeting it will be discharged as before.

J. SMEATON.

Austhorpe, January 9, 1779.

EXPLANATION of the Design for turning Shot Moulds.

THE semi-circle *A B C*, fig. 1st, is supposed to be the horizontal section of an half mould, seen from above, which, together with *C, a, b, c, d, e, f, g, h, A*, is supposed to compleat the whole of the section, and is supposed to be properly fixed upon the arbour or mandrell of a stout chock lathe, capable of turning it with steadiness.

D is the center of the sphere, and, upon an axis passing perpendicularly through this center a frame is supposed to turn, that carries the tool, so as to describe the quadrant *A B*, and by that means the semicircle *A B C*, *i, k, l, m*, is the upper surface of the cutting-tool, *l m* being the cutting edge. Now if the edge *l m* be formed into an arch of a circle, whose radius is less than the sphere to be described, and whose center (suppose at *n*) is capable by the inclination of the frame to be brought into the radius line *A D*, then it is evident, that if, while the mould *f c d e* turns round its axis *D B*, the tool, by gradual inclination of its frame, passes from *A* to *B*, the tool will cut off all superfluous matters that projected beyond its sweep, and also in case the cutting-edge of the tool is regulated to a just height, so as to pass through the center of motion of the mould at *B*, then it is plain that the hollow figure thus described must be an exact hemisphere.

Nothing

Nothing can be more evident and simple than this proposition, the whole difficulty consists in having those exact adjustments that are requisite to perform the necessary conditions, and, at the same time, all the strength and steadiness in the framing that is necessary to work upon and cut clean a mass of cast iron; for this purpose

E F is a section of one cheek, and G H that of the other, of a mortice through the solid metal, for lodging the tool *iklm*, and the prolongation G K is for the reception of an hollow wooden handle, sufficiently long for turning the frame steadily round upon its axis, while the cutting-edge of the tool is describing the quadrant A B.

Fig. 2 shews an upright section of the mould, wherein the same letters denote the same things as in the former figure, *im* now shewing the upright of the tool whose cutting-edge is at *m*, this is pushed towards it works by the screw *op*, which passes through the stud I, affixed to the projecting part G K, and the tool is tightly held down in its mortice or socket by L M, a wedge, which last is slackened or drawn out by *q*, a counter wedge. The socket G H, the prolongation or tail G K, are cast in one solid piece with N O, the upright axis, and those with the projecting ears Q Q, which are supported by and turned round upon the points of the screws R S, by which means the frame is made capable of turning round upon the line R C D A S, passing through the center of the hemisphere A B C, at the same time that the frame will clear the face of the mould when in its most inclined position, as is shewn in fig. 1; where observe, that the dotted square G N shews the section of the upright axis above and below the socket, as at N and O, fig. 2, and the dotted space G N Q, fig. 1, shews the figure or plan of the ears at top and bottom, where they engage with the points of the screws R and S.

Fig. 3 shews the fore front of the mould in the lathe, and the same letters will denote the same matters, besides which T V W X Y Z, &c. denotes a strong frame that surrounds the whole mould, and supports the screws R S upon which the upright moveable turns upon as a center, as already described, which outward frame is to be firmly bolted down upon its flat base upon a stout plank, which plank is to be made to slide with ease and certainty between the checks of the lathe, so as to move in a line parallel to the axis of the mandrill, and to fix at any distance required from the end of the mandrill. It is also supposed, that the axis of the mandrill is adjusted as nearly as possible to a parallelism with the checks and platform of the lathe.

Now the first necessary condition and adjustment is, that the height of the cutting-edge of the tool shall exactly pass through the center of motion of the mould, which will

will best be done by trial, because if it leaves no extuberance in the center, it is plain it has passed through it; if an extuberance is left, it must be by passing either above or below it, and which of them it is may be seen, and the moving frame set higher or lower, by slacking one and tightening the other of the screws R S, and repeating the trial till the surface is left without an extuberance in the center.

The second necessary condition and adjustment is, that the line joining the points of the screws R S shall pass through D, the center of the sphere, that is, through the axis of the mandrell produced, which will also be best known by trial; for this purpose, let a gage circle be turned from thin plate brass to the intended diameter of the ball or sphere of the mould; turn out also the central part of the area, leaving it a ring about $\frac{3}{4}$ or $\frac{1}{2}$ of an inch broad, and cut this in two, which will thereby make two gages: thus provided, let a sweep be made for trial, and it will be known by the gages fitting the swept surface whether the cutting edge of the tool is at its proper distance from the center, because then the gage will fit the swept surface when directed towards the center; if not, let the tool be set forward by the screw *o p*, till they perfectly agree, then running the gage through the center and *beyond* it, if the gage bites hard upon the further quadrant, then the axis of R S is beyond the axis of the mandrell; but if the matter beyond the center leaves the gage, then it is plain that the axis of R S is on the side of the axis of the mandrell that was the cutting side of the mould, and, accordingly, this is corrected by slacking the screw *r r*, and tightening the screw *t t*, or the contrary, till a sweep being taken, the gage every where applies itself to the hollow surface of the mould; and this adjustment being once performed, there is nothing but gradual wear or violence to put it out again, and the gage being applied to every mould, it will always be seen whether any apparent error gradually arises.

The screw *r r* acts upon the stud S, and the screw *t t* upon the stud V, both of which are cast upon the same piece of metal with T V, which carries the screw R, and slides sideway in a chamfered groove in the upper bar of the outward frame, as is more particularly seen in fig. 2. I have described the same kind of slide at the bottom Z S, &c. but this is scarcely necessary; for if the whole frame is bolted down upon the sliding plank, so that the line R S may originally be nearly right, when T V is in the middle, the adjustment may be sufficiently performed by sliding the screw R only, for it is no ways requisite that the line R S should be exactly perpendicular; but only that it passes exactly through the axis of the mandrell produced, but it will be necessary that both the screws R and S should have a counter nut, as at the dotted lines *ww* and *xx*, unless they are made to screw stiffly through their carriage-pieces.

It is to be observed, that, on changing the size of the mould, there ought to be nothing wanting in the way of adjustment, but to set the cutting edge of the tool to its just distance from the center; and as the tool changes in its height by grinding, or a different tool, to see that it passes through the center, that is, supposing the slide of the plank duly performed; and as, upon this slide's being correctly performed, a great deal of the ease and facility of the use of this machine will depend; and as this correctness may seem difficult to arrive at, I will take occasion to make an observation upon lath-making, which may apply itself to several other things in the *Carron* works. To make the heads, &c. of a lath to slide in a right line between the two parallel cheeks with ease and facility, and without vacillation or shaking, is in reality no easy matter to perform; but if the near upright face of the further cheek is shot true and straight with a plane, and the upper face or platform of the two cheeks shot straight and flat, that is, out of winding, all which in carpentry is an easy proposition; if then all the matter composing the seat of the heads is cut away or hollowed off, except about the value of $1\frac{1}{2}$ or 2 inches square, at the four corners, and these prominences brought to a just flat, so as to fit true without shake upon the platform of the lath; if also the far side of the tenant is made to take its bearings at the outsides, so as to apply itself fairly and steadily to the far cheek of the lath; then, if the heads (or any other sliding piece formed in this way) are pushed home against the far cheek with one hand, at the same time that the wedge or screw is tightened by the other, it is plain that these heads or sliders will obey the same right lines that form the upright face of the back cheek and platform, and it is then no matter whether the tenant fills the groove or not, but when slacked will be always at perfect liberty. It seems hardly needful to say, that for correct work the cheeks of a lath should not only be made of dry seasoned wood, but clean and free from cross baits, to prevent their warping after made.

N. B. I am not well acquainted how well the *Carron* metal works with a file, but, to avoid all intricacy and trouble in forging, I would chuse the work to be cast of gun-metal, or perhaps what may be better, 1 ounce of tin to 1lb. of copper.

The mould being supposed hollowed to a true sphere, but a little too deep, then there will be nothing to do but to turn down the face of the rabbat $b A C a$, till the depth $D B$ is exactly half of the width $A C$, and then two such will form a sphere.

It is plain from the figure, that to give the tool a proper bearing in its socket, that one upright frame will not do for all sizes; the present one is drawn at large to answer any size, from a 24lb. shot to a 9lb. another one will go from that to a 3lb. under which it will be proper to have one of a proportionable size; but they will all apply themselves to

the screws R S, and without any other adjustment than that of height. I must, however, observe that the screws R and S must, in proportion to their size, be cut with a fine thread and with sharp stocks, that being first truly turned, they may not salt in sticking, so that when turned round in their sockets, their centers will not sensibly vary. This is a matter requiring attention, but being duly attended to, is not difficult to be practically performed.

J. SMEATON.

Austhorpe, 16th January, 1779.

EXPLANATION of two methods of raising the Slide Carriages for the Carronades.

Fig. 1. A B represents the slide carriage plank.

C D. a piece of wood bolted on crossways upon the under side; this transverse piece is pierced towards each end by a female screw capable of receiving a male screw, one of which is denoted by

E F. a wood screw 10 inches long in the screwed part, and 2 inches long in the head part F, which is well bound with an iron hoop, and perforated crossways with a couple of holes for small handspikes. The position here shewn of the slide plank is horizontal, or parallel to the deck, which, according to the sketch sent, its under side in that position was 12 inches, and in this position the part of the screw shewn clear, viz. F G, is 4 inches; so that when the head F comes close to the transverse piece C D, the end A will be lowered 4 inches, and then the top of the screw will just reach to the upper surface of the slide plank, but without reaching through, so that the hole cut through it to clear the screw, may be covered with a thin plate if thought necessary; but if the screw is unscrewed 4 inches more than is shewn in this position of the figure, so that the top of the screw E will come down to H, then the end A will be raised 4 inches higher, and yet the screw will have 2 inches hold of the box, which, containing three threads, will be sufficient to keep it steady.

Fig. 2. A B represents the slide carriage plank as before; C D shews one of two planks, bolted edgeways under the carriage plank, cut into 6 steps *a b c d e f*, each 1 inch in height, and 2 inches in breadth.

E F

E F shews a piece of wood seen endways, long enough to take both the stepped planks, and stepped also into 6 steps, *g b i k l m*. Now if the height of the lowest step *g* is 4 inches, and increase by 1 inch, then it is evident, if this stepped wood is drawn gradually back, the plank A will descend 1 inch at a time, till the step *g* comes under the step *e*, and the step *b* under the step *f*; then will the end A have descended 4 inches; but if from the present position the stepped wood is pushed in one step at a time, then the end A will rise accordingly, till the step *m* being under the step *b*, and the step *l* under the step *e*, so that the plank A, or rather the point *a*, will be raised 4 inches; and if it is thought expedient to keep them from jumping out of their places, the small staples *n o* being struck in at each end, and the parts lashed together with a marline, this will be sufficient to keep them from shifting the steps upon a discharge, as I apprehend.

J. SMEATON.

Austhorpe, Jan. 20, 1779.

EXPLANATION of the Design for a new Nose-Pipe for *Carron*.

Fig. 1. A·B is supposed to represent the fire stone that now makes the tuire of the furnace, which is supposed to be of the accustomed thickness, but perforated with a round hole of 7 inches diameter, or of such other width as it may be thought proper first to try.

C D E F shews the horizontal section of an iron tube serving for the nose-pipe, also of 7 inches diameter, and checked into the stone, and the joint made good with fire clay, which round tube branches out sideways into

C G H and D I K, which are the sections of two oval tubes, whose axis M L and N L meet the axis of the main tube at L.

O P Q R represent two dove-tailed sliders, that shut up the orifices of the oval side tubes, so as to be air tight; those oval openings are proposed to be 4 inches wide by 6 inches high, so that on removal of the sliders every part of the opening of the tuire into the furnace may be seen, and the arm and instruments introduced by which it may occasionally be luted, and when shut the wind will take its course from the part of the tube E F towards C D, in a parallel direction.

N. B. About 8 or 10 inches of the external part E F is proposed to be kept of a width, but from thence to increase gradually tapering to the size of the main conveyance pipe.

Fig. 2 represents an upright section of the main tube at the line S T upon fig. 1.

E F is the main tube.

O P shews the oval hole with the slider drawn out.

Q R represents the slider in its place, wherein, if thought convenient, *vw* in both figures represents an hole, whereto a piece of plate glass being adapted, and fixed in each slider, the condition of the tuire may, at all times, be inspected, without drawing the sliders, or disturbing the blast.

J. SMEATON.

Austhorpe, May 2, 1779.

A Comparative View of the State of the *Chiron* Furnaces in October, 1776, and in September, 1778.

	No.	Gate drawn.	Head of Water.	Diameter of nozzle-pipe.	Number of Cylinders.	Cube feet of air per minute.	Velocity per second.	Tons of water expended per 24 hours.
State of Furnaces, October, 1776.	1			2½	28	1571	947	16,502
	2			2½	24½	1708	835	16,047
	3			2½	19	1343	691	15,732
	4			2½	12½	1459	881	17,769
	Sums					6081	3394	66,050
	Means					1520	838	
State of Furnaces, September, 1778.	1	1½	3 7	2½	25	1402	846	16,322
	2	0½	4 8½	2½	16	1116	546	11,724
	3	1½	3 10½	2½	17½	1237	562	15,286
	4	0½	3 0½	2½	20½	1309	529	7,396
	5	0½	3 1½	2½	21	1341	542	6,630
	6	0½	3 1½	2½	21	1341	542	6,630
	Sums					6405	3025	57,358
	Means					1281	605	

From.

From the preceding table there appears a great improvement in the dispensing of the water, for in the year 1776 four furnaces expended 66,000 tons per 24 hours, and in the year 1778 five furnaces expended but 57,300.

It is, however, remarkable, that of the last-mentioned quantity, numbers 1 and 3 expended 31,608 tons per 24 hours, while the other three furnaces expended but 25,750, the cause of which disparity it may be proper to enquire; for though every degree of accuracy, I doubt not, has been exerted in the new building of No. 6, and the rebuilding of No. 4, yet there is not that difference in the principle of action that can make these two machines so very much exceed those of No. 1 and 3; for in point of construction I should not expect them to fall short of the performance of No. 4 and 6 more than 20 per cent. This difference I must therefore attribute in a great measure to the different widths of the nose-pipes, which, as I have never heard of their being varied, I take for granted they continue the same they were in the year 1776, that is, as I have put them down. And I have no doubt but that if they, as well as No. 2, were furnished with the same kind of nose-pipes that No. 4 and 6 blow with, that they would then perform within a reasonable difference of those last furnaces; if not, the rest of the difference must be sought for elsewhere, that is, either in the untruth of the cylinders, too great friction of the leathers, a straightening of the wind passages, or a general disrepair of the machines; all which are matters well worth looking into; for if two furnaces can be worked with 14,026 tons per day, this is less than the average quantity for each of the other three, which is 14,444.

Again, although it appears that the expenditure of No. 2 is greatly reduced, owing in part to the removal of Mr. DOWNING's incumbrances, and in part to the reduction of the number of cylinders per minute, (which I suppose was also a consequence of the restitution,) yet if the expenditure of No. 2, viz. 11,724 tons per day, be reduced in proportion of 23 to 20 (which would certainly be the case if that wheel was raised to 23 feet high, like Nos. 4 and 6,) it would still expend 10,195 tons, which is 2799 tons per day more than that of No. 4; and as there does not appear to me any other thing in the construction of the machine No. 2, that should make it fall short of No. 4, this extra expenditure by No. 2 remains to be accounted for, and which in part I doubt not is owing to the difference in its nose-pipe.

That the difference of the friction of the leathers is capable of considerably varying the expenditure of the water, I think appears pretty plain from Nos. 4 and 6, the former consuming more water by $11\frac{1}{2}$ per cent. upon the lesser quantity, than the latter does; and therefore, as they are both as nearly alike as possible, the No. 4 being the last built

built furnace, it seems most probable that the sides of its cylinders were not at that time got to so great a smoothness as those of No. 6, or that casually No. 4 was at that time harder in its leathers.

Now, if we suppose Nos. 1 and 3 to be reformed so as to perform within 20 per cent. of No. 4, and No. 2 reformed so as to perform as well as No. 4, then the expenditures will stand as follows, viz.

No. 1,	8875	No. 4,	7396
No. 2,	7396	No. 6,	6630
No. 3,	8875		
			39,172

From this statement it appears probable, that the consumption of all the five furnaces may be reduced to 39,172 tons per 24 hours; and as *Carron* furnishes in dry seasons 26,400 tons (see report of 6th April, 1777,) there will then only remain 12,772 tons per 24 hours to be provided for out of the reservoirs; and as it is stated in the same report that the home reservoirs alone contain, upon three feet depth to be drawn off, a treasury of 164,268 tons, this would supply *five* furnaces at the rate above stated for near upon 13 days; whereas the same quantity, according to the view of the subject at that time, was not likely to serve *four* furnaces much above seven days. But further, in case No. 1 or No. 3 were laid off in times of scarcity, or that they both together were allowed but 8875 tons per day to keep them alive; then there would be only 3397 tons per day to be provided for out of the reservoirs, which would last the furnaces at this allowance full six weeks, which, together with the other command of water the company already have, seems to render the building a fire-engine of any construction totally unnecessary, especially if the old engine is kept in working order to serve an emergency.

For some time No. 1 led the van of all the works, now it is got into the rear of all; but if you had an opportunity of applying the nose-pipe I transmitted in my letter of the 13th ult. I have reasonable expectation that this furnace would once more lead the van.

J. SMEATON.

Austhorpe, June 11, 1779.

The REPORT of JOHN SMEATON, Engineer, concerning the expediency of opening the temporary Cut and Lock near *Dalderse*, from the canal of *Forth* and *Ghyde* to the river *Carron*.

THE utility of this cut, from *Carron* shore and parts adjacent, appears from its first construction, which was to bring the stones got from the quarries at and near *Kinnaird*, and brought down by the coal waggons to *Carron* shore, there put on board small lighters, was brought through the temporary cut, and brought to build the first land lock, and other works in that quarter; also the lime, pozzelana, and timber were brought for some time that way; and it being a work ordered by the Committee, principally by the advice of Mr. MACKELL, he urged in favour of its expediency, that it would be the properest accommodation to the *Carron* works, and that (in his way of expressing himself) that Company should never get any other. From this it will appear (which I perfectly remember) what were Mr. MACKELL's sentiments concerning it at that time. On examining it, which, at the request of the *Carron* Company, I did the 6th of November last, I found both the cut and lock to all appearance in much better condition than I expected; the principal thing wanted to restore it, will be a little more room, to get earth to strengthen and heighten the banks, equivalent to those of the main canal; and respecting the lock, for any thing that appears, it seems to be likely to want little for some time to come, more than new gates; and the lock is of so small a size, that the head of the lock may be shut by a single gate, in such a way as to occasion much less leakage than the larger pointed gates, and in a mode that I first put in practice upon the river *Cadder* in or about the year 1761, and which the last December I had the pleasure to see in perfect good order, without having had any derangement or repair.

The constant leakage being in this manner secured to all small vessels, having a right to pass the canal proceeding singly upwards, as much water will be saved to the last, or sea reach, as is equal to the difference of area between the temporary lock and the canal locks, which is much more than double, and will be more than equivalent to the consumption of such vessels as may happen to have occasion to go downwards, from the temporary cut; besides, as this reach is of a considerable length, and pretty capacious, and naturally receives the regulating water, and all the leakages from above, there is the least fear of wanting water in this than any other of the reaches.

I remember

I remember myself that this accommodation was frequently mentioned as proper for the Carron Company, but which at that time they did not think sufficiently commodious, and near their works.

As therefore it appears likely, that by opening this temporary cut and lock, there will be a considerable increase of freight-and tolls, without any loss, that it will, for the advantage of the whole, be a proper measure to be carried into execution.

Aulsthorpe, 7th February, 1782.

J. SMEATON.

N. B. I apprehend that small vessels will generally pass single, for it is to avoid waiting for freight that larger vessels are not used.

To the CARRON COMPANY.

GENTLEMEN,

IT is from what has occurred to me in the experience of 30 years in the profession of civil engineering, that I have long entertained an idea that cast iron anchors, I mean those of the largest sizes, would be found of equal if not superior strength to those of wrought iron; and, though in a case where not only the lives of men, but the welfare of nations is concerned, no mercantile consideration ought to take place, nor ought any thing to be spared that can add to the perfection of so very material an utensil as that of the anchor; yet if, upon a fair and full trial, it shall appear that cast iron ones, of a proper composition of metal, are in reality equally or preferably to be depended upon, then the readiness, cheapness, and facility wherewith they are to be produced, appears to me a very sufficient reason (to say nothing of the encouragement of a *British* in contradistinction to a foreign production) why such a fair and full trial should be made as shall be sufficient to put the matter beyond a doubt.

I never supposed that any kind of cast iron would be equal in bearing a stress with that of wrought iron, even of a tolerable quality, provided the size and shape of the matter to be formed of wrought iron is capable of being firmly welded, and united in one solid mass; for this reason, I cannot suppose any anchor can be formed of cast iron, that shall bear a stress equal with one of wrought metal, whose shank is in the smallest part not more than 3 inches, or $3\frac{1}{2}$ inches in diameter: but observing in such large anchors for first and second rate ships of war, as I have had the opportunity of seeing when broken, that the wrought bars of which they are composed are very imperfectly welded and united together in the inside; and having also experienced on the other hand the very great strain that large masses of well-mixed cast iron will bear, when applied to the greatest stresses in mill and engine work, I have been naturally led to put the query, whether beyond some certain medium, that is, whether in those very large and heavy anchors for the largest ships, the substitution of cast iron, instead of wrought, may not be in every respect useful and advantageous.

Had the trial you have communicated to me, made by the officers of his Majesty's yard at *Deptford*, appeared to me conclusive, I should have there rested the matter with them, as fully and sufficiently tried; but, with all due deference to those gentlemen, whose knowledge in their profession entitles them to the greatest respect from the public, I beg leave to say, that this is a new case, and therefore till it is tried, in a manner similar to that in which it is to be used, it is in fact no trial at all.

Had the proposition been to try whether a wrought or a cast iron anchor, or indeed a bar of metal of any size, would best bear the blows of an iron ram or beetle, the mode of trial was perfectly adapted to prove the point; and I am so far satisfied of the fact, as it turned out, that I even wonder that the palms were not broken by the hammers; but I conceive there is nothing like the collision of hard bodies in the real use of an anchor at sea; on the contrary, no stress can possibly be communicated more kindly than that of a ship to its anchor, through the intervention of a long cable. It is possible, in letting go an anchor, it may fall upon a rock, but I conceive an anchor is never let go in foul ground by design, and by choice, but yet it may happen and be necessary. The anchor in its descent having necessarily the cable to haul out after it, and the stock of the anchor, like the log, to haul crossways through the water, the velocity natural to the descent of heavy bodies is hindered from taking place in so great a degree, that let the water be ever so deep, the velocity wherewith it strikes the ground is very moderate, and with this further circumstance that must attend it, that, from the anchor stock and cable both conspiring to act as a rudder, the anchor will necessarily fall with its shank near a perpendicular direction, and therefore have the best chance of impinging upon some part of the crown that is fortified in the best manner to resist blows, as well as every other violence; besides, the rocks below the surface of the sea, being supposed a continuation of the strata above it, and nearly of the same hardness, they are comparative to iron generally soft bodies, and the hardest of them all that lay in masses in this kingdom, that we know of, would, by such a stroke, be *bruised*, less or more; and this is certain, that the effect of a stroke, where either of the bodies is bruised, or will rebound by elasticity, is widely different from what will happen when neither of them will give way in a sensible degree; I must therefore conclude, that there is not, nor can be, any thing in the real use of an anchor that is in any degree analagous to the stroke of an iron ram, much less to such a stroke applied crossways upon its shank.

The windmill, axis and oil-press that you cast for me the year before the last, the former has withstood the fury of all the storms that have happened since, without the least likelihood of injury; and yet one blow of the *Deptford* piling-ram, properly directed, would destroy it. The oil-press is in constant work, and every five or six minutes is subject to an alternate pressure and release from it equivalent to 300 tons of dead weight, tending directly to rend it in two; and yet I believe a single well-directed blow of a sledge hammer would break it. If the length of time of the use of these utensils is not thought sufficient, I must add, that in the year 1755, that is 27 years ago, for the first time, I applied them as totally new subjects, and the cry then was, that if the strongest timbers are not able for any great length of time to resist the action of the powers,

powers, what must happen from the brittleness of cast iron? It is sufficient to say, that not only those very pieces of cast work are still in work, but that the good effect has in the north of *England*, where first applied, drawn them into common use, and I never heard of any one failing. Your own method of breaking up the largest iron guns is also an example to the same purpose, where the blow arising from the fall of an iron ball of 7 or 8 cwt. produces an effect that ten times the power of gunpowder would not; for the action of powder, though very quick, yet differs from the instantaneous action of a blow, in much the like manner as a line does from a surface.

The mode of trial that would appear to me conclusive would be as follows: I would take two anchors, as nearly of a weight and dimensions as possible, the one of wrought, the other of cast iron, not less than three tons weight each (two tons I think too much in favour of the wrought iron for a *first trial*;) and placing them at a competent distance in a right line, with the rings towards each other, for each I would dig a pit in the firm ground, capable of burying both the palms of each anchor: at the bottom of each pit I would fix, edgeways upward, a large elm plank of 10 inches or a foot thick, into the middle of which I would make a moderate perforation of about 3 inches, to receive the point of the fluke of each anchor; these planks I would guard with piles in the securest manner possible, to prevent them, on the application of a great pressure, from moving towards each other, and then well ramming up the whole with earth, so as to bury the anchor, the shanks of each to be inclined upwards, so that the rings may be at or near the surface.

Then having provided two pair of purchase-blocks capable of purchasing 15 or 20 tons each, with suitable tackle-falls, and cap-stands, crabs, or tooth and wheel gins, I would hook one block of each pair to the ring of one anchor, and the other to the other, securing every thing as much as possible; and the tackle-falls being made to go off to the cap-stands, each by a snatch block sideways, it is plain, that whatever strain is upon one anchor, the same will be on the other; I would then proceed to heave till something gave way, and which ever of them kept the ground, after the other, by failure, was drawn out of it, would be the anchor upon which I should be ready, in case of the greatest extremities, to pin my faith.

The expence of the trial I should think no object, for in case the cast-iron anchor was broke, and the other unhurt, there would be no loss but of a little labour, and was I to go to sea, I should chuse the anchor that had been so severely tried, in preference of all others of the same size and kind; but if the wrought iron one gave way,

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by binding or breaking, so as to quit the ground, while the cast-iron one remained unhurt, then a discovery will result worth the price of 20 anchors.

In this manner, if the cast-iron anchor proved the conqueror, I would proceed to try those of a lesser weight, so as to find somewhat nearly the medium, at which the wrought iron anchor would have the preference, keeping always on the safe side of the question.

These, gentlemen, after full consideration, are the result of my genuine sentiments of this subject, which you have desired; and if found useful towards determining a point that may be of much utility to the public service, shall think my pains and study well employed, and remain,

Gentlemen,

With much esteem and respect,

Your most humble servant,

Ausborne, February 7, 1782.

J: SMEATON.

END OF VOL. I.

